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NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the Monthly Weather Review (e. g., January) should be in the hands of the editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

Reprints are made up without covers in the original size and pagination of the Review. They will not be furnished unless specifically requested when the manuscript is submitted.

MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

VOL. 46, NO. 1. JANUARY, 1918. CLOSED MAR. 4, 1918
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INTRODUCTION.

As explained in this Introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS to the MONTHLY WEATHER REVIEW are published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Since August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meterology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observations by Weather Bureau observers and others as reported to the Washington office.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1917. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but *all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.*

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but are collected and published by States at selected section centers. (See cover, p. 3.)

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

CORRIGENDA.

REVIEW, October, 1917:
Page 487, col. 2, next to last line: *for* "later than" *read* "earlier than."

45906—18——1

SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JANUARY, 1918.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Feb. 27, 1918.]

INSTRUMENTS AND EXPOSURES.

In this REVIEW for January, 1916, **44:** 2, will be found descriptions of the exposure of the Marvin pyrheliometer at the various stations, and an account of the method of obtaining and reducing the radiation measurements. These still apply, except as amended in the REVIEW for January, 1917, **45:** 2, and with the further modification that during 1917 the establishment on the campus at the American University, of Camp American University and an extensive laboratory for the U. S. Bureau of Mines, has greatly increased the amount of local smoke in the lower atmosphere. The smoke does not rise to any considerable height, and is quickly cleared away by the wind, so that there is generally opportunity to obtain pyrheliometric readings during intervals when the sky is practically free from smoke.

As noted in the REVIEW for September, 1917, **45:** 440, the spiral-ribbon type of Marvin pyrheliometer in use at Santa Fe, N. Mex., up to the end of April, 1917, has been replaced by a Marvin silver-block pyrheliometer. This latter, and also the Marvin pyrheliometers in use at Madison, Wis., and Lincoln, Nebr., were restandardized during October, 1917, by comparison with Smithsonian silver-disk pyrheliometer No. 1. Practically no change in the constants of these instruments was detected except in the one at Lincoln. The apparent change in the latter instrument, and the corrections to be applied to its readings, are given in the REVIEW for December, 1917, **45:** 574.

In the REVIEW for January and April, 1916, **44:** 4, 179–180, will be found descriptions of the exposure of the Callendar recording pyrheliometer at the different stations, and an account of the method by which records are reduced to heat units. These still apply, except as modified in the REVIEW for January, 1917, **45:** 2.

At Lincoln, as stated in the REVIEW for May, 1917, the publication of the records of solar and sky radiation from the Callendar pyrheliometer, was temporarily suspended pending a redetermination of the constants of the instrument. As shown in the REVIEW for December, 1917, **45:** 574, these constants, and the resulting corrections to back records, have been determined. A new bridge wire, carefully calibrated, was placed on the register at the end of October. The publication of the records of solar and sky radiation (Table 3) for Lincoln is therefore resumed with this number of the REVIEW.

The statements in the REVIEW for January, 1916, and 1917, **44:** 2 and **45:** 2, relative to skylight polarization measurements, and in the REVIEW for January, 1917, **45:** 2, relative to "Radiation Normals" and "Solar constant determinations," still apply.

OBSERVATIONS DURING JANUARY, 1918.

Table 1 is a summary of the measurements made at the different stations with the Marvin pyrheliometer. The departures from normal values indicate that direct solar radiation intensities were very close to normal at Washington, and slightly below normal at the other three stations. Table 3 shows very nearly the normal amount of radiation at Washington and Lincoln, and a pronounced excess, as compared with the normal, at Madison during the latter part of the month.

No skylight polarization measurements were obtained at either Washington or Madison, as the ground was continuously covered with snow.

The readings of the Marvin pyrheliometer indicate steady sky conditions on only one morning at Washington, two mornings at Santa Fe, and one morning at Madison. Even on these most favorable mornings there was disturbance from local smoke at Madison and Santa Fe. The results of extrapolating to zero air mass, given in Table 4, should therefore be given little weight. Except for the one series at Madison they indicate low values for the solar constant.

TABLE 1.—*Solar radiation intensities during January, 1918.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1918. A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Jan. 3	.....	.....	1.28	1.16	1.14	1.11	1.05	1.00	0.96	0.92
4	.....	.....	1.37	1.28	1.20	1.13	1.05	1.00	0.95	0.91
8	.....	.....	.....	1.02	0.96	0.90	0.73	0.62	0.58	.....
17	.....	.....	.....	1.06	0.92	0.84	0.76	0.70	.....	.....
19	.....	.....	1.16	1.06	.....	0.88	0.80	0.73	0 64	0.60
21	.....	.....	1.14	1.05	0.93	0.83	0.73	0.65	0.60	.....
Monthly means	.....	.....	**1.24**	**1.11**	**1.03**	**0.95**	**0.85**	**0.78**	**0.75**	**0.81**
Departure from 10-year normal	.....	.....	**+0.03**	**+0.02**	**+0.03**	**+0.02**	**−0.01**	**−0.01**	**+0.02**	**+0.11**
P. M.										
Jan. 3	.....	.....	.....	1.09	0.98	.....	.....	.....	.....	.....
10	.....	.....	.....	1.15	1.03	0.94	0.86	0.79	.....	.....
12	.....	.....	.....	1.01	0.99	0.94	0.88	0.82	0.80	.....
19	.....	.....	.....	.....	.....	.....	0.86	0.80	.....	.....
21	.....	.....	.....	0.92	.....	.....	.....	.....	.....	.....
22	.....	.....	.....	1.21	1.16	1.11	1.06	0.98	.....	.....
Monthly means	.....	.....	.....	**1.08**	**1.04**	**1.00**	**0.92**	**0.85**	**(0.80)**	.....
Departure from 10-year normal	.....	.....	.....	**−0.03**	**+0.00**	**+0.05**	**+0.03**	**+0.03**	**+0.03**	.....

TABLE 1.—*Solar radiation intensities during January, 1918*—Contd.

Madison, Wis.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	65.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1918. A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Jan. 14					1.39	1.30	1.22	1.15	1.10	
15				1.28					0.96	
19			1.28	1.15	1.02	0.91	0.82	0.73		
29				1.37	1.29	1.21	1.13	1.06	1.01	0.96
Monthly means			(1.28)	1.27	1.23	1.14	1.06	0.98	1.02	(0.96)
Departure from 8-year normal			−0.07	−0.08	−0.04	−0.03	−0.02	−0.01	−0.09	−0.00
P. M.										
Jan. 7							1.12			
8						1.24	1.22	1.19		
9					1.34	1.29		1.19		
19				1.15	1.02					
28				1.24	1.22	1.21	1.19			
31					1.34					
Monthly means				(1.20)	1.23	1.25	1.18	(1.19)		
Departure from 8-year normal				−0.11	−0.01	+0.06	+0.04	+0.05		

Lincoln, Nebr.

A. M.										
Jan. 3				1.06	0.92	0.80				
4					1.01	0.97	0.93	0.89		
7				1.25	1.16	1.08				
11				1.39	1.33	1.26				
14				1.37						
23			1.36							
28			1.30							
Monthly means			(1.33)	1.27	1.10	1.03	(0.93)	(0.89)		
Departure from 3-year normal			−0.06	−0.02	−0.10	−0.10	−0.14	−0.11		
P. M.										
Jan. 3					0.99	0.89	0.81	0.75		
12				1.32	1.27	1.20	1.14	1.07	1.02	
14				1.29	1.24	1.20	1.16	1.11	1.07	1.04
23				1.27	1.25	1.22	1.13	1.06		
Monthly means				1.29	1.19	1.13	1.06	1.00	(1.04)	(1.04)
Departure from 3-year normal				−0.03	−0.05	−0.07	−0.07	−0.06	−0.02	

Santa Fe, N. Mex.

A. M.										
Jan. 4						1.28				
16							1.24			
21				1.34						
22			1.51	1.44	1.35	1.26				
23			1.50			1.24				
24			1.49	1.42		1.29				
29		1.52	1.45	1.38	1.32	1.26				
30					1.36	1.28				
Monthly means		(1.52)	1.49	1.40	1.34	1.27	(1.24)			
Departure from 6-year normal		−0.03	−0.02	−0.03	−0.05	−0.05	−0.04			
P. M.										
Jan. 22							1.15			
29				1.33						
Monthly means				(1.33)			(1.15)			
Departure from 2-year normal				−0.06			−0.05			

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C. Date.	8 a. m.	8 p. m.	Madison, Wis. Date.	8 a. m.	8 p. m.	Lincoln, Nebr. Date.	8 a. m.	8 p. m.	Santa Fe, N. Mex. Date.	8 a. m.	8 p. m.
1918.	mm.	mm.	1918.	mm.	mm.	1918.	mm.	mm.	1918.	mm.	mm.
Jan. 3	0.97	1.02	Jan. 7	1.88	1.45	Jan. 3	1.96	2.87	Jan. 4	3.30	4.37
4	0.74	0.86	8	0.91	1.19	4	3.00	4.37	16	1.78	2.49
8	1.96	1.52	9	0.74	1.19	7	0.97	2.06	21	0.86	1.96
10	1.88	2.06	14	0.64	0.79	11	0.28	0.23	22	0.91	1.78
12	4.75	1.25	15	0.56	0.86	12	0.53	0.81	23	1.88	2.26
17	3.15	2.62	19	0.58	0.97	14	0.74	1.37	24	1.45	2.87
19	1.19	1.07	28	1.45	1.12	23	2.62	3.99	29	1.19	2.36
21	1.19	1.60	29	0.64	0.71	28	0.46	1.02	30	1.78	2.49
22	2.36	2.06	31	0.46	0.53						

TABLE 3.—*Daily totals and departures of solar and sky radiation during January, 1918.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals. Washington.	Madison.	Lincoln.	Departures from normal. Washington.	Madison.	Lincoln.	Excess of deficiency since first of month. Washington.	Madison.	Lincoln.
1918.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Jan. 1	224	28	122	62	−116	−58	62	−116	−58
2	94	143	135	−68	−3	−47	−6	−119	−105
3	242	101	201	79	−46	18	73	−165	−87
4	244	146	180	81	−2	−5	154	−167	−92
5	108	51	35	−55	−98	−151	99	−265	−243
6	92	36	122	−72	−115	−66	27	−380	−309
7	49	216	367	−115	64	178	−88	−316	−131
8	224	233	84	59	79	−107	−29	−237	−238
9	121	226	210	−45	70	17	−74	−167	−221
10	233	190	296	67	3	101	−7	−164	−120
11	60	114	118	−107	−45	−79	−114	−209	−199
12	208	143	276	40	−18	77	−74	−227	−122
13	255	248	216	86	85	15	12	−142	−107
14	108	229	266	−62	64	63	−50	−78	−44
15	119	245	205	−52	78	0	−102	0	−44
16	195	203	206	22	93	−2	−80	93	−46
17	237	256	231	63	84	19	−17	177	−27
18	210	279	207	34	105	−8	17	282	−35
19	226	252	176	49	75	−43	66	357	−78
20	232	246	217	51	67	−5	117	424	−83
Decade departure							+124	+388	+37
21	272	166	267	91	−15	41	208	409	−42
22	152	272	241	−31	88	12	177	497	−30
23	245	116	248	60	−70	15	237	427	−15
24	246	194	227	59	6	−9	296	433	−24
25	148	282	128	−41	71	−112	255	504	−136
26	139	128	183	−53	−65	−60	202	439	−196
27	74	217	86	−120	21	−161	82	460	−357
28	57	228	325	−139	30	75	−57	490	−282
29	283	259	271	84	58	17	27	548	−265
30	40	202	324	−161	−1	67	−134	547	−198
31	175	323	254	−28	117	−6	−162	664	−204
Decade departure							−279	+240	−121
Excess or deficiency since first of year. { cal.									
per cent.							−3.0	+12.5	−2.1

TABLE 4.—*Solar radiation intensities for zenithal sun, reduced to mean solar distance of the earth, and resulting approximate values of the solar constant.*

[Gram-calories per minute per square centimeter of normal surface.]

Stations.	Dates.	Radiation Intensity. m=1	m=0	Solar Constant.
	1918.	calories.	calories.	calories.
Washington, D. C.	Jan. 4	1.50	1.70	1.76
Santa Fe, N. Mex.	Jan. 24	1.60	1.76	1.85
	Jan. 29	1.55	1.70	1.78
Madison, Wis.	Jan. 29	1.61	1.85	1.91

MATHEMATICAL THEORY OF SOUND RANGING.

By HARRY BATEMAN, Ph. D.

[Throop College of Technology, Aeronautical Laboratory, Pasadena, Cal., Jan. 8, 1918.]

1. *Introduction.*—The development of the art of concealing large guns so that they can not be easily seen by hostile airmen or observers in kite balloons has brought into prominence the study of methods of locating powerful guns by means of observations of the time of arrival of the sound of their gunfire at one or more observing stations. There are really two distinct problems to be discussed.

(1) The simple case when the flash is seen and the distance of the gun is to be determined from the observed interval of time between the instants when the flash is seen and the report is heard at a single station.

(2) The more complex case when the flash is not seen. The sound of the report must now be timed at three or four observing stations and the position of the gun estimated from the observed differences in time. A small error in the timing of the sound is more disastrous in the second case than in the first, consequently an accurate method of timing the arrival of the sound is very necessary for the successful application of the second method.

Artillery chronoscopes have been used for the simple method of ranging, and some improvements in design have been made during the present war. Whereas formerly a chronoscope enabled time to be measured accurately to a fifth of a second, a modern instrument will record hundredths of a second.[1] Chronoscopes of this type are used in testing the nerves of would-be air pilots and it is found that a successful candidate will stop the pointer in fifteen-hundredths of a second after hearing a sound, while an unsuccessful candidate may allow twenty or even thirty hundredths of a second to pass. Now, it is unlikely that the personal equation of an observer will remain absolutely constant and an error of one-tenth of a second would certainly be disastrous in the second method of sound ranging and troublesome even in the first, consequently it is advisable to have instrumental means of recording automatically the time at which the sound arrives and methods of measuring time with great accuracy have been skillfully developed.

The possibility of utilizing sound to locate a large gun is to some extent due to the nature of the sound produced by gunfire. In front of the gun the sound is much more intense than it is behind, in fact, as far as the production of sound is concerned, the gun acts something like a searchlight, directing its beam along the line of fire. As a result of this the sound is much more intense in the forward direction than it would be if it were produced by the explosion of a shell. Thus to the German generals behind the lines every shot from the British guns appeared to stand out above the dull heavy roar of their own guns as a sharp staccato note like a loud drum tattoo, whence the name drum-fire (Trommelfeuer).[2] Again, the reports which have been heard in England seem to have come from German guns; for instance, the sound of gunfire, which was heard very distinctly on the evening of July 10, 1917, was attributed to the German bombardment on the Nieuport front, which commenced at 5 p. m.[3]

In both methods of sound ranging it is necessary to take into account the meteorological conditions, for the velocity of sound depends on the temperature, humidity, and composition of the air, while the wind affects the mode of propagation. The velocity of sound may be calculated from the formula [4]

$$V = V_0\left(\frac{TH}{T_0(H-0.378h)}\right)^{\frac{1}{2}}$$

where T is the absolute temperature, H is the barometric pressure, and h is the vapor pressure of water vapor, while V_0 is the velocity of sound in dry air at temperature T_0. The variation in composition can generally be neglected under ordinary conditions unless the sound ascends to a great height before it reaches the observer, but it is conceivable that on the battle field the presence of large quantities of smoke may affect the sound in a manner which is not quite negligible. A further difficulty arises on account of the fact that the very intense waves caused by the detonation of explosives have a velocity distinctly greater than that of ordinary sound,[5] and it must not be assumed without experimental verification that the velocity varies with the temperature and humidity of the air in the same way as the ordinary velocity of sound. It seems advisable, then, to invent a method of sound ranging in which the velocity of sound is eliminated altogether, and this is one of the objects of the present paper.

Whether it is of importance in military operations or not, the meteorological aspect of the problem of sound ranging is of some theoretical interest, because there are indications that it may eventually be possible to obtain some knowledge of the conditions in the upper atmosphere by a method of timing sound signals.

At present the mathematical theory is based on the idea of sound rays and is more accurate for sound of high frequency than for sound of low frequency. The work which is being done in the development of methods of producing and recording sounds of high frequency will thus be valuable for the above purpose, while a standard phone or sound generator may also be useful.

2. *Sound ranging from observations at one station when the sound travels horizontally.*—Let O (fig. 1) represent the position of the observer, G the position of the gun. The direction OG is known from the observation of the flash, while the time, t, which the sound takes to travel from G to O is also known. Let v be the velocity of the wind, AO the direction of the wind; then if the length AO represents vt, the length AG will represent Vt, and since the angle AOG is known, the position of G may be found by a simple geometrical construction or by triangulation.

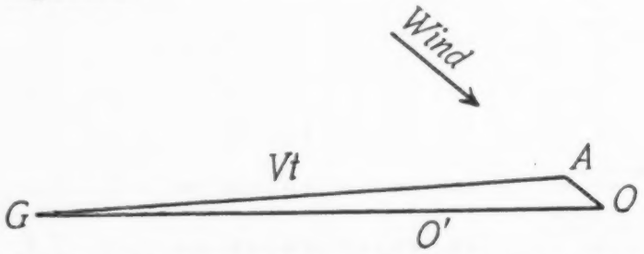


FIG. 1.—Sound ranging for the gun G from one station when the sound travels horizontally.

This method fails if the sound travels to the observer by a path through the upper air, and so it is useful to have a test which will enable an observer to find out

[1] An artillery chronoscope with a balance beating hundredths of a second has been brought out. See Engineering, May 19, 1916, p. 485.
[2] Compare *G. F. Sleggs* in Nature, London, Aug. 23, 1917.
[3] *See* Nature, London, July 19, 1917.

[4] *O. D. Chwolson.* Lehrbuch der Physik. v.2, p. 30.
[5] For a discussion of this matter and references see *L. V. King*, in Journal of the Franklin Institute, March, 1917, p. 274.

when this occurs. The following test is based on the theory developed in §4.

Let a second observation be made at a point O' on OG, then if the sound travels through the upper air, the interval between the times of travel at O and O' should be less than it would be if the sound traveled in a horizontal direction. This test will, of course, fail if the sound produced by the firing of the gun travels with a velocity greater than the ordinary velocity of sound.

If an object reflects sound back to the observer, its distance may be estimated by noting the interval between the production of the sound at O and the arrival of the echo. If T denotes this interval, the distance of the object is given by the formula—

$$2d=\frac{VT\left(1-\frac{v^2}{V^2}\right)}{\sqrt{1-\frac{v^2}{V^2}\sin^2\theta}}$$

where θ is the angle between the direction of the wind and the direction of the object. If v is small compared with V so that $\frac{v^2}{V^2}$ may be neglected, this method may be used to find the distance of the object when its direction is not known.

If it were possible to produce at O an intense sound having a frequency equal to one of the natural frequencies of the gun and obtain a return sound from the gun, this method might be used with advantage and a gun located by means of observations at two stations before it was even fired.

3. *Sound ranging from observations at a number of stations when the sound travels horizontally.*—When the sound travels over the surface of the earth and this is treated as flat, the problem of locating a gun from observations at three stations A', B', C', may be solved as follows: the first step is to reduce the problem to the case when there is no wind. Let t_a, t_b, t_c, be the times at which the sound is recorded at these stations and let T be any convenient time. Draw lines $A'A$, $B'B$, $C'C$, in a direction opposite to the wind and let the lengths of these lines represent the distances $v(t_a-T)$, $v(t_b-T)$, $v(t_c-T)$, respectively, where v is the velocity of the wind. We must now determine the position of a point G at which a gun can be fired so as to be heard at A, B, and C, at times t_a, t_b, and t_c, respectively, when there is no wind. Let $GA=V(t_a-T_0)$, then if we draw a line GG' in a direction opposite to the wind to represent the length $v(T-T_0)$, the point G will indicate the position of the gun. To determine the point G we can make use of the hyperbolas H and H_1 defined by the equations $GA-GB=V(t_a-t_b)$, and $GB-GC=V(t_b-t_c)$, respectively, or we can draw circles of radii $V(t_a-T)$, $V(t_b-T)$, $V(t_c-T)$, with their centers at A, B, C, respectively. The point G is then the center of a circle which has the same kind of contact with each. If the latter method is to be used the computer may find it useful to have a set of metal disks whose radii differ successively by small amounts, the circle which touches the three circles may then be found very quickly by trial.

When the distance AB is small compared with the distance of the gun the hyperbola H may be replaced by its asymptote which bisects AB and makes an angle with AB whose cosine is the ratio of t_a-t_b to the time which sound would take to travel from A to B. When this method is used it is useful to have observations at two pairs of stations, one pair of stations being at a considerable distance from the other.

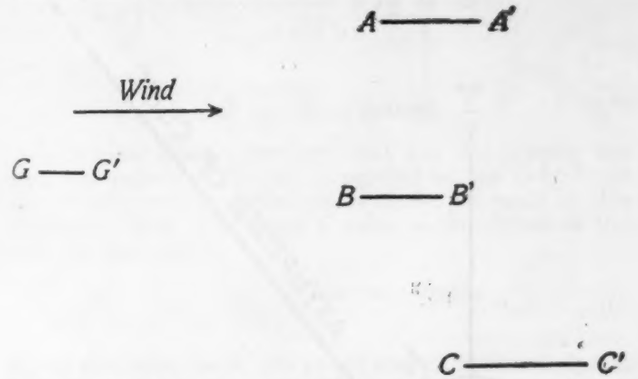
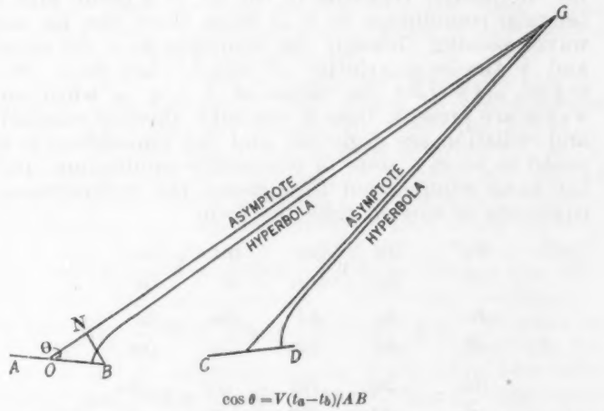


FIG. 2.—Sound ranging for the gun G' from three stations, A', B', C', when the sound travels over the flat surface of the earth.

When the velocity of the sound is unknown use may be made of observations at two trials of stations $A'B'C'$ and $P'Q'R'$. Let t_1, t_2, t_3, be the times at which the sound arrives at A, B, and C, respectively; and let $x_1, y_1; x_2, y_2; x_3, y_3$, be the rectangular co-ordinates of the derived points A, B, C, in the reduced problem (fig. 4); also let r_1, r_2, r_3, be the distances of an arbitrary point from A, B, and C, respectively; then the point G lies on the circular cubic whose equation is

$$r_1(t_2-t_3)+r_2(t_3-t_1)+r_3(t_1-t_2)=0.$$



$\cos\theta=V(t_a-t_b)/AB$

FIG. 3.—Method using two pairs of stations, AB being small in comparison with the distance OG.

If the distances between A, B, and C are small compared with the distance of the gun, the circular cubic may be replaced by its asymptote whose equation, when the origin is at the centre of the circle ABC, is

$$x[x_1(t_2-t_3)+x_2(t_3-t_1)+x_3(t_1-t_2)]+y[y_1(t_2-t_3)+y_2(t_3-t_1)+y_3(t_1-t_2)]$$
$$=\frac{2\triangle^2(t_2-t_3)(t_3-t_1)(t_1-t_2)}{[x_1(t_2-t_3)+x_2(t_3-t_1)+x_3(t_1-t_2)]^2+[y_1(t_2-t_3)+y_2(t_3-t_1)+y_3(t_1-t_2)]^2}$$

where $\triangle$ is the area of the triangle ABC. The denominator on the right hand side may also be written

$$a^2(t_1-t_2)(t_1-t_3)+b^2(t_2-t_3)(t_2-t_1)+c^2(t_3-t_1)(t_1-t_2),$$

where a, b, and c are the lengths of the sides of the triangle ABC. The asymptotes of the two cubics associated with ABC and PQR, respectively, meet in a point G from which an approximate position of the point G' may be derived.

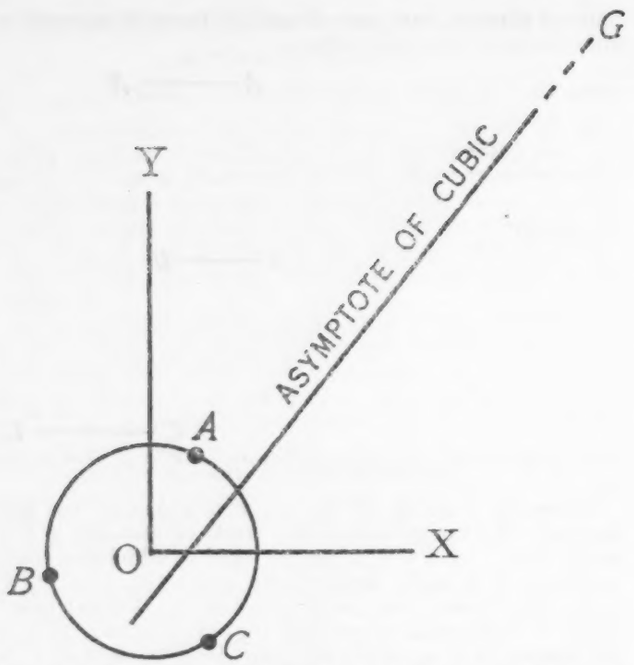


FIG. 4.—Method using two triads of stations, the gun G lying on the circular cubic or its asymptote.

4. *The general theory of rays of sound.*—Let (u, v, w) be the component velocities of the air at a point with rectangular coordinates (x, y, z) when there are no sound waves passing through the atmosphere, ρ the density, and V the local velocity of sound. Let $u+u'$, $v+v'$, $w+w'$, $\rho(1+\epsilon)$ be the values of u, v, w, ρ, when sound waves are present, then if viscosity, thermal conduction and radiation are neglected and the atmosphere is supposed to be in a state of convective equilibrium, and of the same composition throughout, the hydrodynamical equations of motion take the form

$$\frac{du'}{dt}+u'\frac{\partial u}{\partial x}+v'\frac{\partial u}{\partial y}+w'\frac{\partial u}{\partial z}+V^2\frac{\partial \epsilon}{\partial x}=0,$$

$$\frac{dv'}{dt}+u'\frac{\partial v}{\partial x}+v'\frac{\partial v}{\partial y}+w'\frac{\partial v}{\partial z}+V^2\frac{\partial \epsilon}{\partial y}=0,$$

$$\frac{dw'}{dt}+u'\frac{\partial w}{\partial x}+v'\frac{\partial w}{\partial y}+w'\frac{\partial w}{\partial z}+V^2\frac{\partial \epsilon}{\partial z}=0,$$

$$\rho\frac{d\epsilon}{dt}+\frac{\partial}{\partial x}(\rho u')+\frac{\partial}{\partial y}(\rho v')+\frac{\partial}{\partial z}(\rho w')=0,$$

$$\frac{d}{dt}\equiv\frac{\partial}{\partial t}+u\frac{\partial}{\partial x}+v\frac{\partial}{\partial y}+w\frac{\partial}{\partial z}.$$

In obtaining these equations we have assumed that u', v', w', ϵ, are small, that all changes take place adiabatically, and that no condensation of water vapor occurs in the atmosphere.

If the disturbance which produces the sound waves is initially confined to a limited region, a wave of discontinuity of some type will travel outward. The front of this wave will satisfy the partial differential equation of the characteristics of the above system of equations.[6] The simplest way of obtaining this equation is to assume that $u', v', w', u, v, w, \rho$, are continuous but that the first derivatives of u', v', w', ϵ, suddenly change in value as we cross the moving surface $F(x, y, z, t)=0$. We thus obtain the equations

$$\frac{\partial u'}{\partial F}\frac{dF}{dt}+V^2\frac{\partial \epsilon}{\partial F}\frac{\partial F}{\partial x}=0, \quad \frac{\partial v'}{\partial F}\frac{dF}{dt}+V^2\frac{\partial \epsilon}{\partial F}\frac{\partial F}{\partial y}=0,$$

$$\frac{\partial w'}{\partial F}\frac{dF}{dt}+V^2\frac{\partial \epsilon}{\partial F}\frac{\partial F}{\partial z}=0,$$

$$\rho\frac{\partial \epsilon}{\partial F}\frac{dF}{dt}+\rho\left(\frac{\partial u'}{\partial F}\frac{\partial F}{\partial x}+\frac{\partial v'}{\partial F}\frac{\partial F}{\partial y}+\frac{\partial w'}{\partial F}\frac{\partial F}{\partial z}\right)=0.$$

from which we find that

$$\left(\frac{dF}{dt}\right)^2=V^2\left\{\left(\frac{\partial F}{\partial x}\right)^2+\left(\frac{\partial F}{\partial y}\right)^2+\left(\frac{\partial F}{\partial z}\right)^2\right\}.$$

When a solution of this equation has been found, the rays are given by the equations of the bicharacteristics, namely,

$$\frac{dx}{u\frac{dF}{dt}-V^2\frac{\partial F}{\partial x}}=\frac{dy}{v\frac{dF}{dt}-V^2\frac{\partial F}{\partial y}}=\frac{dz}{w\frac{dF}{dt}-V^2\frac{\partial F}{\partial z}}=\frac{dt}{\frac{dF}{dt}}$$

If, however, the solution is given as a complete integral

$$F=t-f(x, y, z, \alpha, \beta)=0$$

involving the two arbitrary constants α and β, the rays are obtained by combining the above equation with the equations

$$\frac{\partial f}{\partial \alpha}=0, \qquad \frac{\partial f}{\partial \beta}=0,$$

as in the Hamiltonian theory for rays of light.[7]

When there is no wind, we have the general theorem of Straubel,[8] which may be enunciated as follows: Let P and Q be two points on a ray and let rays consecutive to PQ and forming a small pencil of solid angle $d\omega$ with its vertex at P cut out an area dS' on a plane through Q perpendicular to the ray, while a similar small pencil of rays of solid angle $d\omega'$ with its vertex at Q cuts out an area dS on a plane through P perpendicular to the ray, then we have the relation

$$\frac{d\omega\, dS}{V^2}=\frac{d\omega'\, dS'}{V'^2}.$$

This theorem has not yet been generalized so as to be applicable to the case in which a wind is blowing.

A transformation theory based on the fundamental quadratic form

$$(dx-udt)^2+(dy-vdt)^2+(dz-wdt)^2=V^2dt^2$$

may be used to group together various distributions of u, v, w, V, in which the problem of determining the sound rays is soluble by means of function of a given type. Inversion is a particular transformation which may be used with advantage.

When the air is stratified in horizontal layers so that the wind is blowing horizontally and V depends only on

[6] See *Hadamard:* Propagation des ondes. Paris, 1903.

[7] See *Herman*, Geometrical Optics, Chapter XIII.

[8] *R. Straubel* in Phys. Zeitschr., 1903, 4: 114-117; *T. Levi-Civita* in Rend., Ac. del Lincei, 1915, 24: 666.

one coordinate Z, the sound rays may be found in a well-known manner as follows:[7]

Let us write

$$\frac{\partial F}{\partial x}=\alpha, \qquad \frac{\partial F}{\partial y}=\beta,$$

then, if $F=t-f(x,y,z,\alpha,\beta)$ as before, we find that

$$t=f(x,y,z,\alpha,\beta)=\int\frac{dz}{V}\sqrt{(1+u\alpha+v\beta)^2-V^2(\alpha^2+\beta^2)}-\alpha x-\beta y$$

and the equations of the rays are obtained by writing

$$\frac{\partial f}{\partial \alpha}=0, \quad \frac{\partial f}{\partial \beta}=0.$$

The same result may also be obtained as follows:[8] Let (θ, ϕ) be the spherical polar coordinates of the wave-normal at a point with rectangular coordinates (x, y, z), then we have the equations

$$\left.\begin{aligned}&\phi=\phi_0,\\ &V\operatorname{cosec}\theta+u\cos\phi+v\sin\phi=V_0\operatorname{cosec}\theta_0+u_0\cos\phi+v_0\sin\phi\\ &\qquad\qquad=\lambda \text{ (say)}\end{aligned}\right\}(1)$$

which express that the velocity and direction of the line or intersection with the horizon of the tangent plane to the wave front remain constant. The suffixes are used here to indicate values of quantities *at the level of the ground*.

The ray velocity is obtained by compounding the wind velocity with the velocity of sound directed along the normal to the wave front, hence the equations determining the rays are

$$\left.\begin{aligned}dx&=udt+Vdt\sin\theta\cos\phi,\\ dy&=vdt+Vdt\sin\theta\sin\phi,\\ dz&=Vdt\cos\theta,\end{aligned}\right\}(2)$$

The range and time of passage of sound which travels up into the air and down again are thus given by the equations

$$\left.\begin{aligned}x&=2\int_0^Z\frac{V^2\cos\phi+us}{\sqrt{s^2-V^2}}\cdot\frac{dz}{V},\\ y&=2\int_0^Z\frac{V^2\sin\phi+vs}{\sqrt{s^2-V^2}}\cdot\frac{dz}{V},\\ t&=2\int_0^Z\frac{s}{\sqrt{s^2-V^2}}\cdot\frac{dz}{V},\end{aligned}\right\}(3)$$

where

$$s=\lambda-u\cos\phi-v\sin\phi,$$

and Z is defined by the equation $s=V$.

These equations give

$$\lambda t-x\cos\phi-y\sin\phi=2\int_0^Z\sqrt{s^2-V^2}\,\frac{dx}{V}. \qquad (4)$$

Now let the initial direction of the ray vary slightly so that θ and ϕ become $\theta+d\theta$ and $\phi+d\phi$, then

$$\lambda dt+td\lambda-dx\cos\phi-dy\sin\phi+(x\sin\phi-y\cos\phi)d\phi$$
$$=2\int_0^Z\frac{s(d\lambda+u\sin\phi d\phi-v\cos\phi\,d\phi}{\sqrt{s^2-V^2}}\cdot\frac{dz}{V},$$

or

$$\lambda dt=dx\cos\phi+dy\sin\phi. \qquad (5)$$

It is clear from symmetry that the line joining the two end points of the ray is parallel to the tangent at the vertex, let the displacement dx,dy, be made in this direction; then, if $u, v,$ and V refer to the vertex of the ray, we shall have

$$\frac{dx}{u+V\cos\phi}=\frac{dy}{v+V\sin\phi}=\frac{dx\cos\phi+dy\sin\phi}{\lambda}=dt. \qquad (6)$$

If, on the other hand, the sound travels horizontally the above equations are replaced by

$$dt_0=\frac{dx}{u_0+V_0\cos\phi_0}=\frac{dy}{v_0+V_0\sin\phi_0}$$
$$=\frac{dx\cos\phi+dy\sin\phi}{u_0\cos\phi+v_0\sin\phi+V_0\cos(\phi-\phi_0)}.$$

Now

$$\lambda=u_0\cos\phi+v_0\sin\phi+V_0\operatorname{cosec}\theta_0$$
$$>u_0\cos\phi+v_0\sin\phi+V_0\cos(\phi-\phi_0),$$

hence $dt<dt_0$. This means that the time of travel of the sound increases more rapidly with the range when the sound travels horizontally than when it travels by a curved path through the upper air.

If it is found by means of the test based on this inequality, that the sound does travel to the observer through the upper air we are met with the difficulty that the wind velocity to be used in reducing the problem of sound ranging to the case of no wind, is the wind velocity at the vertex of the ray and this is unknown. It is reasonable to assume, however, that when the vertex is high this velocity is about equal to the gradient-wind velocity and is roughly the same for all the rays that come into consideration. With this assumption, our method of reduction is legitimate and the position of G may be found by the method depending on the use of two triads of observations, for if we make two independent displacements (dx,dy) and (dx_1,dy_1) the equations

$$\lambda dt=dx\cos\phi+dy\sin\phi,$$
$$\lambda dt_1=dx_1\cos\phi+dy_1\sin\phi,$$

are of the same form but with different values of λ whether the sound travels horizontally or through the upper air; also the quantity λ, like the velocity of sound, is eliminated in the above method.

The gradient-wind velocity may, of course, be derived from the weather map when this is available.

When the vertex of a ray is not very high the difference in the times of travel of this ray and of one that is supposed to travel horizontally between the same end points, is generally so small as to be almost negligible and probably the best plan is to make the calculations just as if all the sound traveled horizontally.

It should be noticed that if the velocity of the wind is less than the velocity of sound there are always two

[8] *Lord Rayleigh*, Theory of Sound, v. 2, p. 133.

directions, ϕ, for a ray which has its vertex at a given level, for which the relation $\phi=\phi_0$ is satisfied. These directions are given by the equation

$$uv_0-u_0v+(Vv_0-V_0v)\cos\phi+(uV_0-u_0V)\sin\phi=0,$$

and are real because the inequality

$$(Vv_0-V_0v)^2+(uV_0-u_0V)^2>(uv_0-u_0v)^2$$

is satisfied since it may be written in the form

$$[(u_0^2+v_0^2)V-(uu_0+vv_0)V_0]^2>(uv_0-u_0v)^2[u_0^2+v_0^2-V_0^2].$$

It generally happens, however, that for some values of ϕ the rays that start horizontally at a given height Z bend upward instead of downward, and so are not rays that start from the ground. Using primes to denote differentiations with regard to z, we find on applying the equation

$$V\operatorname{cosec}\theta+u\cos\phi+v\sin\phi=\lambda$$

to the level Z and a consecutive level, that

$$(V'+u'\cos\phi+v'\sin\phi)dz+V(\sec d\theta-1)=0;$$

hence a ray bends upward or downward according as

$$V'+u'\cos\phi+v'\sin\phi\lesseqgtr 0$$

When there are directions for both upward and downward rays, the two angular regions are separated by two radii whose directions are given by the equation

$$V'+u'\cos\phi+v'\sin\phi=0.$$

These directions are real if $u'^2+v'^2>V'^2$. In this case the height Z may be called *anticlastic* (symbol $\pm$). If $u'^2+v'^2\leqq V'^2$ the height Z is said to be *positively synclastic* when rays which start horizontally bend downward, and *negatively synclastic* when rays which start horizontally bend upward (symbols + and −).

Let us now consider a ray which leaves the ground horizontally, then bends upward and finally returns to the ground. If this ray also possesses the property $\phi=\phi_0$ it follows from equation (4) that the time of travel is greater than if the sound traveled horizontally between the two end points of the ray. For since $\phi=\phi_0$ the quantity λ is the same in both cases and so also is $x\cos\phi+y\sin\phi$, but in the first case we have

$$\lambda t-x\cos\phi-y\sin\phi>0$$

while in the second case the left-hand side is zero. This proves the theorem.

Now let us gradually increase the range, then since the time of travel for a ray through the upper air increases less rapidly for a ray which travels through the upper air than for a ray which travels horizontally, it follows that the times gradually become equal and eventually the time of travel through the upper air may become less than the time that sound would take to travel horizontally.

When the wind blows uniformly in one direction the condition $\phi=\phi_0$ is satisfied in the case of a ray which starts either in the direction of the wind or in the opposite direction.

When there is no wind blowing the condition $\phi=\phi_0$ is satisfied for every ray and when V increases upward every ray which goes up into the air is brought down to the ground again, while the time of travel through the upper air is always less than if the sound traveled horizontally between the end points of the ray. To prove this we notice that if R denotes the range, equations (1) and (5) give

$$\frac{dR}{dt}=V=V_0\operatorname{cosec}\theta_0>V_0,\qquad\text{therefore}\quad\frac{R}{V}>t.$$

An interesting case arises when we adopt H. Mohn's assumption [10] that V is a linear function of z to a first approximation. The equations $V=V_0+\sigma z$,

$$t=2\int_0^z\frac{\lambda dz}{V\sqrt{\lambda^2-V^2}},\qquad R=2\int_0^z\frac{Vdz}{\sqrt{\lambda^2-V^2}},$$

then give

$$\sigma R=2\sqrt{\lambda^2-V_0^2},\qquad \sigma t=2\cosh^{-1}\frac{\lambda}{V_0},$$

$$\sigma R=2V_0\sinh\frac{\sigma t}{2},$$

and it is clear from this equation that $R>V_0t$. The problem of sound ranging under such conditions is rather interesting, for when timings are made at two stations A_1 and A_2 the locus of the gun is given by the equations

$$\sigma R_1=2V_0\sinh\frac{\sigma t_1}{2},\qquad \sigma R_2=2V_0\sinh\frac{\sigma t_2}{2},$$

which determine a bicircular quartic with A_1 and A_2 as foci when the difference t_1-t_2 is given. As this difference varies we get a system of bicircular quartics (fig. 5) with two, but not four, real foci in common and this corresponds to the system of confocal hyperbolas in the ordinary problem of sound ranging.

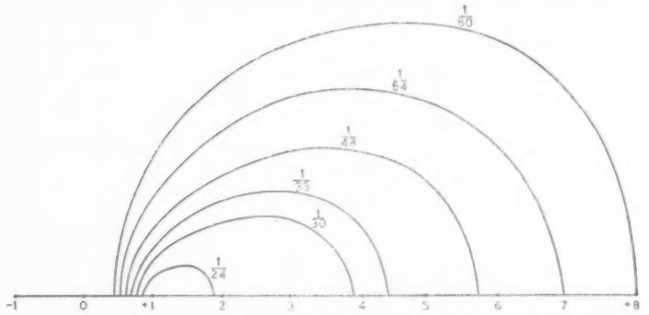


FIG. 5.—System of bicircular quartics with two real foci in common at −1 and +1, and the parametric equations

$r_1=16\sinh(\theta+\alpha)$, $r_2=16\sinh\theta$;

the numbers indicate the value of $\sinh^2\frac{1}{2}\alpha$ for the different quartics.

Although the present problem of sound ranging is only of theoretical interest, it may be remarked that when observations are made at three stations A_1,A_2,A_3, the gun may be located by using charts on which the bicircular quartics of the required type are drawn, one system being associated with A_1,A_2, and another system with A_2,A_3. It is important to notice that the same charts can be used with different values of σ by simply altering the dimensions of the figure A_1A_2, B_1B_2 keeping its form unaltered.

[10] *H. Mohn* in Annalen der Hydrographie, 1892, 1893, 1895.

If in the present circumstances an observer hears first by a direct ray and afterward by a ray reflected from the ground, then if t and t' are the two intervals between the firing of the gun and the observations we have

$$\sigma R = 2V_0 \sinh\frac{\sigma t}{2}, \qquad \sigma R = 4V_0 \sinh\frac{\sigma t'}{4}.$$

To get an idea of the magnitude of the interval $t'-t$, let us consider the following ways of satisfying the equation $2\sinh\frac{\sigma t}{4} = \sinh\frac{\sigma t}{2}$:

1) $\frac{\sigma t'}{4} = 0.22, \qquad \frac{\sigma t}{2} = 0.43018, \qquad \sigma(t'-t) = 0.01964;$

2) $\frac{\sigma t'}{4} = 0.1, \qquad \sigma(t'-t) = \frac{2}{1019}.$

The sound which is reflected takes slightly longer to reach the observer and the difference in time is about 0.0223 of the total time of travel in the first case and about 0.00497 in the second. Thus if the sound takes 10 seconds to travel, the interval is about $\frac{1}{5}$ second in the first case and about $\frac{1}{20}$ second in the second. The value of σ in the first case is 0.088, representing an increase in V of 8.8 meters per second in 100 meters; in the second case σ is 0.04 and represents an increase in V of 4 meters per second in 100 meters. These rates of increase in V are not abnormally large, for instance at Drexel, Nebr., on May 8, 1916, at 6:21 a. m. the temperatures at altitudes of 396 and 500 meters were 8° and 11.8° C., respectively, while the wind velocity and humidity between these levels were practically constant. A calculation of the velocity of sound indicates that in this case V increases by about 4.5 meters per second in 104 meters.

5. *The initial radius of curvature of a ray which starts horizontally.*—Let us write $u = u_0 - az$, $v = v_0 - bz$, $V = V_0 - \sigma z$, then for a ray which starts in a horizontal direction and then bends upward

$$S = V_0 + a\cos\phi + b\sin\phi,$$

and we have to a first approximation

$$x = \int_0^z \frac{(V_0\cos\phi + u_0)\,dz}{\sqrt{2V_0 z(a\cos\phi + b\sin\phi + \sigma)}} = 2\sqrt{z}\cdot\frac{V_0\cos\phi + u_0}{\sqrt{2V_0(a\cos\phi + b\sin\phi + \sigma}}$$

$$y = \int_0^z \frac{(V_0\sin\phi + v_0)\,dz}{\sqrt{2V_0 z(a\cos\phi + b\sin\phi + \sigma)}} = 2\sqrt{z}\cdot\frac{V_0\sin\phi + v_0}{\sqrt{2V_0(a\cos\phi + b\sin\phi + \sigma)}}$$

The initial radius of curvature is thus

$$\rho = \frac{(V_0\cos\phi + u_0)^2 + (V_0\sin\phi + v_0)^2}{2V_0(a\cos\phi + b\sin\phi + \sigma)}$$

It should be noticed that ρ becomes infinite when $a\cos\phi + b\sin\phi + \sigma = 0$, while maximum and minimum values of ρ are roots of the equation

$$(u_0 - \rho a)^2 + (v_0 - \rho b)^2 = \left(\rho\sigma - \frac{V_0^2 + u_0^2 + v_0^2}{2V_0}\right).$$

When a ray does not start in a horizontal direction but goes up into the air and returns to the earth, the radius of curvature at its vertex may be found by means of a similar formula using of course the values of u_0, v_0, V_0, a, b, σ, for the level of the vertex.

6. *The case in which the gun and the observer are at different levels.*—In this case the limits of integration in the equations (3) are altered so that if (x_1, y_1, z_1) are the coordinates of a gun, (x_2, y_2, z_2) those of the observer, we have for a ray without a vertex

$$\lambda(t_2 - t_1) - (x_2 - x_1)\cos\phi - (y_2 - y_1)\sin\phi = \int_{z_1}^{z_2} \sqrt{s^2 - V^2}\frac{dz}{V},$$

while for a ray with a vertex

$$\lambda(t_2 - t_1) - (x_2 - x_1)\cos\phi - (y_2 - y_1)\sin\phi = \int_{z_1}^{z} \sqrt{s^2 - V^2}\frac{dz}{V} + \int_{z_2}^{z} \sqrt{s^2 - V^2}\frac{dz}{V}.$$

Now let the positions of the gun and observer vary, then we find that

$$\lambda dt_2 - dx_2\cos\phi - dy_2\sin\phi \mp dz_2\cot\theta_2 = \lambda dt_1 - dx_1\cos\phi - dy_1\sin\phi - dz_1\cot\theta_1. \quad (7)$$

This relation is analagous to one which occurs in the general theory of geodesics.[11] It is important to notice that if the observer and gun are in motion so that

$$dx_2 = a_2 dt_2, \qquad dy_2 = b_2 dt_2, \qquad dz_2 = c_2 dt_2,$$
$$dx_1 = a_1 dt_1, \qquad dy_1 = b_1 dt_1, \qquad dz_1 = c_1 dt_1,$$

the above equations give

$$\frac{dt_2}{dt_1} = \frac{\lambda - a_1\cos\phi - b_1\sin\phi - c_1\cot\theta_1}{\lambda - a_2\cos\phi - b_2\sin\phi \mp c_2\cot\theta_2} = \frac{V_1\operatorname{cosec}\theta_1 + (u_1 - a_1)\cos\phi + (v_1 - b_1)\sin\phi - c_1\cot\theta_1}{V_2\operatorname{cosec}\theta_2 + (u_2 - a_2)\cos\phi + (v_2 - b_2)\sin\phi \mp c_2\cot\theta_2}.$$

This is the form which Doppler's principle assumes for an atmosphere stratified in parallel planes. It should be noticed that this formula differs slightly from the empirical formula suggested in my previous note [12] and gives $dt_1 = dt_2$ when the source of sound and observer are both stationary. In this case, then, there is no change of frequency, as might be expected. The above formula does not, however, quite cover the case for which the empirical formula was suggested, because now the wind velocity and velocity of sound are the same at the locations of the gun and the observer, if these are at the same level, whereas in the case referred to the wind velocity was supposed to be different in the two places.

When a source of sound is higher than the observer, or is moving through the air, it is possible that some meteorological data may be obtained by noting the change in pitch when the sound is heard at the earth's surface and applying our general formula for Doppler's principle. C. E. Stromeyer [13] has already suggested that gustiness might be recorded by observing what in

[11] *T. Levi-Civita*, Rendiconti, Accad. dei Lincei, 1915, 24: 666.
[12] *H. Bateman*, Doppler's principle for a windy atmosphere. MONTHLY WEATHER REVIEW, Sept., 1917, 45: 441.
[13] *Stromeyer* in Nature, London, Apr. 26, 1917.

German is called "wimmern," that is, a variation in the sounds heard from church bells during gusty weather.

7. *Derivation of meteorological data by means of sound ranging.*—When the positions of the gun and the observer are known, the timing of the sound furnishes some information with regard to the structure of the atmosphere.

In the first place, if the sound travels through the upper air and the gun and the observer are at the same level, the equations

$$\lambda dt = dx\cos\phi + dy\sin\phi, \qquad \lambda\delta t = \delta x\cos\phi + \delta y\sin\phi,$$

corresponding to two different displacements of the observer, determine the angle ϕ and the quantity λ. Since the direction of the gun is known a displacement can be made directly away from the gun and then the equations (6) determine the quantities

$$u + V\cos\phi, \qquad v + V\sin\phi,$$

for the level of the vertex of the ray. Now, let the source of sound be raised a small distance dz, then it follows from equation (7) that

$$\lambda(dt_2 - dt_1) = -dz_1\cot\theta_1.$$

This equation determines the angle θ_1 which is denoted below by θ_0.

Returning to the case in which both the gun and observer are on the ground, let us vary the initial direction of a ray in such a manner that Z remains constant. We then have

$$dx = -2\int_0^Z \frac{V dz}{(s^2 - v^2)^{\frac{3}{2}}}[(s^2 - V^2)\sin\phi.d\phi + (u + s\cos\phi)ds].$$

Now dx must be finite, hence ds must vanish when $z = Z$. Using the value

$$s = V_0\operatorname{cosec}\theta_0 + (u_0 - u)\cos\phi + (v_0 - v)\sin\phi,$$

we find that we must have

$$V_0\operatorname{cosec}\theta_0.\cot\theta_0.d\theta_0 = [(u - u_0)\sin\phi - (v - v_0)\cos\phi]d\phi.$$

Now θ_0, ϕ, and $u\sin\phi - v\cos\phi$, are known from the previous observations and V_0, u_0, v_0, can be determined from meteorological observations at the level of the ground, hence we can determine the relation between $d\theta_0$ and $d\phi$. This means that we can trace on the ground a curve which is the locus of the extremities of rays which start at a given point and have their vertices at a given height.

By using observations at two points of this curve for which the values of ϕ are ϕ_1 and ϕ_2, respectively, we can calculate the quantities

$$u + V\cos\phi_1, \qquad u + V\cos\phi_2,$$
$$v + V\sin\phi_1, \qquad v + V\sin\phi_2,$$

and so determine the values of u, v, and V.

Drawing curves for different altitudes of the vertex of a ray, we may obtain an idea of the structure of the atmosphere as far as the variations of u, v, and V, are concerned, but unfortunately we can not assign the value of Z for each curve.

An idea of the structure of the atmosphere may also be obtained in a rough way by a study of the regions of audibility after a great explosion. Data of the required type have been collected on several occasions [14] and some types of sound areas have been correlated with certain weather conditions. In Japan, according to Prof. Omori, 9 out of 11 recent Asama-yama explosions with double sound-areas occurred in the winter, while 10 out of 11 explosions with single sound-areas occurred in the summer months.

8. *Some numerical data.*—At Prof. C. F. Marvin's suggestion I have made some numerical calculations, using the data obtained at Drexel, Nebr., in 1916. The velocity of sound in the following table is calculated on the assumption that the velocity for dry air at 0°C is 333.4 meters per second, the value given by Chwolson. In column 10 the symbols indicate the characteristics of the different levels as explained in § 4; it will be seen that in most cases a level is anticlastic, but when the temperature decreases upward it is quite common for all rays which start horizontally at a given level, to be refracted upward. In order that rays may go up into the air and down again it is necessary that the total change in wind velocity in ascending to some level should be greater in magnitude than the decrease or negative increase in the velocity of sound. So far no case has been found, in the summer, in which rays starting nearly horizontally are brought down to the ground for every horizontal direction; but in January when the wind velocity is low such cases do occur.

TABLE 1.—*Velocities of sound and characteristics of different levels in six cases based on actual data secured at Drexel Aerological Station, Nebraska.*

(1) **April 11, 1916.** (Supplement No. 7, p. 9.)

Time.	Altitude.	Temperature.	$\frac{\Delta t}{100}$.	Pressure.	Vap. press.	Velocity of sound.	Wind. Dir.	Wind. Vel.	Symbol.*	Remarks.
	m.	°*C.*	°*C.*	*mbar.*	*mbar.*	*m. p. s.*		*m./s.*		
A. M.										
9:39.....	396	19.0	.....	966.7	7.69	345.326	se	8.9	.....	All rays refracted upward.
.....	500	18.5	.....	955.0	7.67	345.036	se	9.1	−	
.....	750	17.2	.....	927.1	7.26	344.252	se	9.7	−	

(2) **May 13, 1916.** (Supplement No. 7, p. 27.)

P. M.										
12:45....	396	12.4	.....	964	13.82	341.815	ese	6.3	.....	Some rays are brought down to the ground.
.....	500	11.8	.....	952	13.29	341.431	ese	8.0	±	
12:50....	743	10.5	0.55	924.7	12.06	340.592	se	12.0	±	
.....	750	12.6	.....	924	13.86	341.979	se	10.1	±	
1:15.....	871	14.4	−3.05	910.6	15.42	343.180	sse	8.5	±	

(3) **May 5, 1916.** (Supplement No. 7, p. 22.)

A. M.										
6:08.....	396	13.2	.....	965.3	8.50	341.935	sw	5.4	.....	Some rays are brought down to the ground.
6:10.....	487	20.5	−8.02	955.1	10.61	346.419	sw	14.1	±	
.....	500	20.5	.....	954	10.37	346.404	sw	13.9	±	
.....	750	20.5	.....	926.1	8.20	346.231	sw	11.4	±	

(4) **May 19, 1916.** (Supplement No. 7, p. 29.)

P. M.										
5:49.....	396	13.6	.....	967.8	13.55	342.511	se	4.0	.....	Some rays are brought down to the ground.
.....	500	12.8	.....	955.6	13.01	342.008	se	4.9	±	
.....	750	10.7	.....	927.7	11.45	340.667	se	7.2	±	
6:51.....	937	9.2	0.81	907.2	10.48	339.710	se	8.9	±	
6:52.....	983	10.4	−2.28	902.2	11.35	340.502	se	8.9	+	

(5) **Jan. 3, 1916.** (Supplement No. 5, p. 6.)

A. M.										
8:54.....	396	−4.1	.....	980.4	4.07	331.147	s	4.9	.....	All rays refracted downward.
.....	500	−1.4	.....	967.2	4.62	332.847	s	5.5	+	
9:01.....	669	2.9	−2.56	947.4	5.27	335.519	s	6.6	+	

(6) **May 4, 1916.** (Supplement No. 7, p. 21.)

A. M.										
6:49.....	396	10.0	.....	959.5	7.98	339.986	ssw	10.3	.....	Some rays are brought down to the ground.
.....	500	14.4	.....	948.1	9.51	342.730	ssw	17.2	±	
6:51.....	613	19.1	−4.19	935.1	11.28	345.655	ssw	24.6	±	

* Z is positively (+) or negatively (−) synclastic, or anticlastic (±). (See p. 8.)

[14] *See* for example,, *S. Fujiwhara* in Bull., Central met. obs'y., Tokyo, 1916, pt. 2; and *C. Davison* in Quarterly review, July, 1917.

9. *The magnitude of the error in sound ranging.*—Let us consider the reduced problem in which the time is given for two stations A and B, then G lies on one branch of a hyperbola with A and B as foci. Let a be the semi-major axis of this hyperbola and let $AB=2c$, then the equation of the hyperbola, when the origin is taken at 0, the middle point of AB, is—

$$\frac{x^2}{a^2}-\frac{y^2}{c^2-a^2}=1. \qquad (8)$$

If the times vary slightly on account of errors in timing, while A and B remain fixed, a varies and the hyperbola is changed into a confocal hyperbola while the increments of x,y,a, are connected by the relation

$$\frac{2xdx}{a^2}-\frac{2ydy}{c^2-a^2}=2ada\left[\frac{x^2}{a^4}+\frac{y^2}{(c^2-a^2)^2}\right]=2\frac{da}{a}\left[1+\frac{c^2y^2}{(c^2-a^2)^2}\right].$$

The total displacement of G is least when

$$dx=\lambda\frac{x}{a^2},\ dy=-\frac{\lambda y}{c^2-a^2},\ \lambda=ada,$$

and then

$$ds=\sqrt{(dx)^2+(dy)^2}=ada\left[\frac{x^2}{a^4}+\frac{y^2}{(c^2-a^2)^2}\right]^{\frac{1}{2}}=da\left[1+\frac{c^2y^2}{(c^2-a^2)^2}\right]^{\frac{1}{2}}.$$

If, on the other hand, $dx=0$, we have

$$dy=-\frac{c^2-a^2}{ay}da\left[1+\frac{c^2y^2}{(c^2-a^2)^2}\right].$$

To get an idea of the magnitude of these quantities let us take the case when $c^2=2a^2$,

then $\quad ds=da\left[1+\frac{4y^2}{c^2}\right]^{\frac{1}{2}}, \qquad dy=-\frac{a}{y}da\left[1+\frac{4y^2}{c^2}\right].$

If $V=1{,}100$ feet a second, an error in timing of 1/100 second may mean an error in $2a$ of 11 feet.

The following table then gives the magnitude of the error in ranging for different values of the ratio $y:c$.

TABLE 2.—*Magnitude of error in ranging.*

$y:c$	ds	dy
	Feet.	*Feet.*
$\sqrt{2}$	16½	24½
$\sqrt{12}$	38½	55
$\sqrt{42}$	71½	101
$\sqrt{420}$	225½	315

When the wind is blowing, the points A and B are displaced slightly from their true positions on account of the error in timing, but if the wind velocity is as large as 20 feet a second the displacement caused by an error of 1/100 second in timing is only 2 feet.

Let us now estimate the magnitude of the error introduced when the asymptote of the hyperbola is used instead of the hyperbola. Since the equation of the asymptotes is

$$\frac{x^2}{a^2}-\frac{y^2}{c^2-a^2}=0,$$

we find on subtracting from (8) that $2ydy=c^2-a^2$. Writing $c^2=2a^2$ as before, we find that if $AB=2c=1{,}000$ feet, $y=10{,}000$ feet, $dy=6\frac{1}{4}$ feet.

The error introduced by using the asymptote of the circular cubic, in the method in which the velocity of sound is eliminated, is more difficult to determine; it is probably larger than in the case just discussed but still not large enough to be important.

To get some idea of the error in time arising from the circumstance that sound may travel through the upper air instead of along a horizontal path, let us consider the simple case in which there is no wind and the velocity of sound increases upward. The range is now given by the formula

$$R=\frac{2V_0}{\sigma}\sinh\frac{\sigma t}{2}$$

Taking $\sigma=0.04$, $t=10$ seconds, we have

$$\frac{\sigma t}{2}=0.2,\ \sinh\frac{\sigma t}{2}=0.20134,\ R=55{,}000\times0.20134,$$

$$\frac{R}{V_0}-t=50\times0.00134=0.067.$$

The difference in time is thus about 7/100 second in a range of about 2 miles and may cause a serious error in sound ranging if no attention is paid to the effect of the meteorological conditions.

MEAN VALUES OF FREE-AIR BAROMETRIC AND VAPOR PRESSURES, TEMPERATURES, AND DENSITIES OVER THE UNITED STATES.

By WILLIS RAY GREGG, Meteorologist in Charge.

[Dated: Division of Aerological Investigations, Weather Bureau, Jan. 31, 1918.]

Although numerous free-air observations have been made, and are being made, in different parts of the United States, mean values of certain reduced data have thus far not been published. Temperature, humidity, and wind data, as observed at Mount Weather, Va., have been summarized in the Bulletin of the Mount Weather Observatory, 1913, v. 6, pts. 4 and 5, and similar summaries of observations by means of sounding balloons at different points in this country have been presented in the same publication, v. 4, pt. 4, and in the MONTHLY WEATHER REVIEW, July, 1914, and May, 1916. A paper on "The Planetary System of Convection" by Dr. (now Major) Wm. R. Blair, appeared in the MONTHLY WEATHER REVIEW, April, 1916. The conclusions reached in the latter paper were based on all available free-air observations made in the United States and in other parts of the world. More recently a brief summary, with special reference to the needs of aeronauts, has been prepared by Maj. W. R. Blair and published by the National Advisory Committee for Aeronautics as Report No. 13. None of these summaries has included free-air pressures and densities. As a knowledge of these data is of great importance in connection with aviation and the firing of projectiles, it has been thought best to publish in brief tabular form their average values as determined from all available observations thus far made by the U. S. Weather Bureau in this country. At a later time similar tables will be furnished for additional stations which are now being established.

Table 1, below, gives mean monthly, seasonal, and annual free-air pressures, temperatures, vapor pressures, and densities as observed at Mount Weather, Va. Pressures and vapor pressures are expressed in both metric and dynamic units, temperatures on the centigrade and approximate absolute (273 + t°C) scale, and

densities in percentages of standard density (dry air at 760 mm. pressure, 0° C., and latitude 45°, =1.293 kgm. per cu. m., approximately) and in kilograms per cubic meter. The temperatures have been published in the Bulletin of the Mount Weather Observatory, v. 6, pt. 4, and are repeated here for convenience in considering them in connection with the other data. They are based on five years' observations. The pressures are based on three years', and the vapor pressures on one year's observations. The vapor pressures are given only to 3 kilometers, observations at higher levels being too few in number to be accepted as reliable means. The values in the first column under "Density" have been computed from the formula

$$\rho = \frac{b - 0.378e}{T} \times K,$$

in which

ρ = density,

b and e = barometric and vapor pressures, respectively,

T = approximate absolute temperature ($273 + t$°C),

K = a constant, depending upon the conditions of pressure and temperature that are accepted as standard, viz, 760 mm. pressure and 0° C., or $K = 0.35921$.

The values in the second column are obtained by multiplying those in the first column by 1.293 kgm. per cu. m. Values at sealevel and at an altitude of 500 meters have been estimated by extrapolation. In computing densities above 3 kilometers estimated values of vapor pressure, based on those in Table 3, have been used. The correction due to vapor pressure at these altitudes is, however, small.

For the convenience of those who prefer these values in English units Table 2 has been prepared. In this table altitudes are expressed in feet, barometric and vapor pressures in inches of mercury, temperatures in Fahrenheit degrees, and densities in percentages of standard density (dry air at 29.92 in. pressure, 32°F., and latitude 45°, = 0.08071 lbs. per cu. ft.) and in pounds per cubic foot.

Tables 3 and 4 give data similar to those in Tables 1 and 2, respectively, but are based on sounding balloon observations at Fort Omaha, Nebr., Indianapolis, Ind., Huron, S. Dak., and Avalon, Cal. These observations are too few in number to give reliable monthly means, but the seasonal and especially the annual means are considered fairly representative of conditions in the Central and Western States.

It should, of course, be understood that the figures published in all of these tables are not strictly average values, as they are based for the most part upon observations made in the daytime. The temperatures in the lower levels are somewhat higher than the 24-hour means and the densities therefore slightly lower. In general they may be said to represent very closely daytime conditions up to about 2,000 meters (1¼ miles) above sealevel and both day and night conditions at higher altitudes.

Table 5 presents the mean annual atmospheric pressures, temperatures, and densities at various heights above sea level as observed in England. This table was published by Capt. H. T. Tizard, R. F. C., in The Aeronautical Journal, April-June, 1917, page 109, and contains "the mean results of a long series of actual observations made by Mr. W. H. Dines, F. R. S."

For convenience of comparison the annual values of density, given in Tables 1, 3, and 5 are presented in Table 6. This table shows that, at low altitudes, higher densities obtain over England than over the United States. The former are not corrected for vapor pressure, but this correction would be small. The difference is due mainly to the lower temperatures in England. At altitudes above 3 kilometers the agreement is close. So far as is known to the writer free-air densities have not been published for other countries, and further comparisons are therefore not possible at this time.

Much assistance in the preparation of Tables 1 to 4, inclusive, has been rendered by Mr. William S. Cloud, of this division.

TABLE 1.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va.*

January.

Altitudes above M. S. L.	Pressures.		Temperatures.		Vapor pressures.		Densities.	
m.	*mm.*	*mb.*	°*C.*	°*A.*	*mm.*	*mb.*	%	*kg./cu. m.*
0	761.2	1014.9	− 0.2	272.8	2.09	2.79	100.1	1.295
500	718.7	958.2	− 1.3	271.7	2.06	2.75	94.9	1.227
526	716.5	955.3	− 1.3	271.7	2.06	2.75	94.6	1.224
1000	675.1	900.1	− 2.0	271.0	1.98	2.64	89.4	1.156
1500	634.9	846.5	− 2.9	270.1	1.80	2.40	84.3	1.091
2000	595.2	793.6	− 4.0	269.0	1.67	2.23	79.4	1.027
2500	559.1	745.5	− 5.7	267.3	1.42	1.89	75.1	0.971
3000	524.3	699.1	− 8.2	264.8	1.10	1.47	71.1	0.919
3500	491.8	655.7	−10.9	262.1	.....	.....	67.4	0.871
4000	462.0	616.0	−13.6	259.4	.....	.....	64.0	0.827
4500	* 439.9	* 586.5	−16.4	256.6	.....	.....	* 61.6	* 0.796
5000	.....	.....	−19.4	253.6	.....	.....	.....	.....

February.

0	762.0	1016.0	1.1	274.1	3.18	4.24	99.7	1.289
500	717.5	956.6	− 0.7	272.3	2.41	3.21	94.5	1.222
526	715.5	954.0	− 0.8	272.2	2.40	3.20	94.3	1.219
1000	674.1	898.8	− 2.4	270.6	1.95	2.60	89.4	1.156
1500	632.8	843.7	− 3.4	269.6	1.76	2.35	84.2	1.089
2000	593.7	791.6	− 4.8	268.2	1.50	2.00	79.4	1.027
2500	558.0	744.0	− 6.8	266.2	0.93	1.24	75.2	0.973
3000	523.7	698.3	− 9.0	264.0	0.74	0.99	71.2	0.921
3500	491.6	655.5	−12.0	261.0	.....	.....	67.6	0.874
4000	463.3	617.7	−14.8	258.2	.....	.....	64.4	0.833
4500	434.5	579.3	−17.7	255.3	.....	.....	61.1	0.790
5000	.....	.....	−21.1	251.9	.....	.....	.....	.....

March.

0	761.7	1015.6	6.9	279.9	4.93	6.57	97.5	1.261
500	718.8	958.4	4.7	277.7	4.19	5.59	92.8	1.200
526	716.1	954.8	4.6	277.6	4.13	5.51	92.5	1.195
1000	675.4	900.5	2.5	275.5	3.46	4.61	87.9	1.136
1500	634.9	846.5	0.7	273.7	2.75	3.67	83.2	1.076
2000	596.6	795.4	− 1.3	271.7	2.14	2.85	78.8	1.018
2500	560.2	746.9	− 3.6	269.4	1.43	1.91	74.6	0.965
3000	526.3	701.7	− 6.2	266.8	0.89	1.19	70.8	0.916
3500	495.0	660.0	− 8.9	264.1	.....	.....	67.3	0.870
4000	464.6	619.5	−11.8	261.2	.....	.....	63.9	0.826
4500	435.8	581.1	−15.1	257.9	.....	.....	60.7	0.785
5000	414.7	552.9	−18.1	254.9	.....	.....	58.4	0.756

April.

0	761.0	1014.6	13.9	286.9	7.92	10.56	94.9	1.227
500	718.6	958.1	10.5	283.5	6.68	8.91	90.7	1.173
526	716.2	954.9	10.4	283.4	6.62	8.83	90.5	1.170
1000	676.5	902.0	7.4	280.4	5.48	7.31	86.4	1.117
1500	636.5	848.6	4.6	277.6	4.52	6.03	82.1	1.062
2000	598.5	798.0	1.7	274.7	3.63	4.84	78.1	1.010
2500	562.5	750.0	− 0.9	272.1	2.85	3.80	74.1	0.958
3000	528.6	704.8	− 3.6	269.4	2.17	2.89	70.4	0.910
3500	496.1	661.5	− 6.7	266.3	.....	.....	66.8	0.864
4000	464.8	619.7	− 9.7	263.3	.....	.....	63.4	0.819
4500	433.8	578.4	−13.0	260.0	.....	.....	59.9	0.774
5000	402.2	536.3	−16.0	257.0	.....	.....	56.2	0.727
6000	* 362.8	* 483.7	−22.7	250.3	.....	.....	* 52.1	* 0.673
7000	.....	.....	−29.3	243.7	.....	.....	.....	.....

* Based on few observations; figures not regarded as reliable.

TABLE 1.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va.*—Continued.

May.

Altitudes above M. S. L.	Pressures.		Temperatures.		Vapor pressures.		Densities.	
m.	*mm.*	*mb.*	°*C.*	°*A.*	*mm.*	*mb.*	%	*kg./cu. m.*
0	760.2	1013.6	20.9	293.9	11.32	15.09	92.4	1.195
500	718.7	958.2	17.1	290.1	9.40	12.53	88.5	1.145
526	716.4	955.2	17.0	290.0	9.30	12.40	88.3	1.142
1000	677.6	903.4	13.4	286.4	7.49	9.99	84.6	1.094
1500	638.4	851.2	9.9	282.9	5.58	7.44	80.8	1.045
2000	601.0	801.3	6.6	279.6	4.02	5.36	77.0	0.996
2500	565.5	754.0	3.5	276.5	2.83	3.77	73.3	0.948
3000	531.7	708.9	0.5	273.5	2.18	2.91	69.7	0.902
3500	499.9	666.5	− 2.6	270.4	.....	.....	66.3	0.858
4000	468.5	624.8	− 5.7	267.3	.....	.....	62.9	0.813
4500	438.6	584.9	− 9.1	263.9	.....	.....	59.7	0.771
5000	409.6	546.1	−13.1	259.9	.....	.....	56.6	0.732
6000	352.9	470.5	−19.5	253.5	.....	.....	50.0	0.647
7000	.....	.....	−25.1	247.9	.....	.....	.....	.....

June.

0	758.9	1011.8	23.2	296.2	14.30	19.07	91.4	1.182
500	718.1	957.4	19.9	292.9	12.00	16.00	87.5	1.132
526	716.0	954.6	19.7	292.7	11.88	15.84	87.3	1.129
1000	677.5	903.3	16.7	289.7	9.70	12.93	83.5	1.080
1500	638.7	851.6	13.7	286.7	7.41	9.88	79.7	1.030
2000	601.6	802.1	10.8	283.8	5.63	7.51	75.9	0.981
2500	566.5	755.3	8.0	281.0	4.02	5.36	72.2	0.934
3000	533.1	710.8	5.1	278.1	2.90	3.87	68.7	0.888
3500	501.6	668.8	1.9	274.9	.....	.....	65.4	0.846
4000	471.6	628.9	−1.5	271.5	.....	.....	62.3	0.806
4500	443.2	590.9	−4.9	268.1	.....	.....	59.3	0.767
5000	416.5	555.4	−7.7	265.3	.....	.....	56.4	0.729

July.

0	759.0	1012.0	26.6	299.6	17.05	22.73	90.2	1.167
500	717.8	957.0	23.0	296.0	13.87	18.49	86.5	1.118
526	716.4	955.2	22.8	295.8	13.74	18.32	86.4	1.117
1000	678.4	904.5	19.3	292.3	10.91	14.55	82.9	1.072
1500	640.1	853.4	15.9	288.9	8.54	11.38	79.2	1.024
2000	603.2	804.2	12.7	285.7	6.28	8.37	75.5	0.977
2500	568.1	757.5	9.7	282.7	4.52	6.02	72.0	0.930
3000	535.4	713.9	6.8	279.8	3.04	4.05	68.6	0.887
3500	503.7	671.6	3.5	276.5	.....	.....	65.3	0.845
4000	474.0	632.1	0.1	273.1	.....	.....	62.3	0.805
4500	444.3	592.5	− 3.2	269.8	.....	.....	59.1	0.764
5000	417.8	557.2	− 6.3	266.7	.....	.....	56.2	0.727
6000	*372.0	*496.1	−12.1	260.9	.....	.....	*51.2	*0.662
7000	.....	.....	−17.9	255.1	.....	.....	.....	.....

August.

0	762.3	1016.4	25.2	298.2	20.35	27.13	90.9	1.175
500	720.2	960.2	21.7	294.7	15.82	21.09	87.1	1.126
526	717.7	956.9	21.5	294.5	15.59	20.78	86.8	1.123
1000	679.6	906.1	18.3	291.3	11.51	15.35	83.3	1.077
1500	640.9	854.5	15.3	288.3	8.99	11.99	79.4	1.027
2000	604.3	805.7	12.5	285.5	6.63	8.84	75.7	0.979
2500	569.4	759.2	9.8	282.8	4.73	6.30	72.1	0.932
3000	536.3	715.1	6.8	279.8	3.48	4.64	68.7	0.888
3500	504.5	672.7	3.8	276.8	.....	.....	65.3	0.845
4000	474.9	633.3	0.7	273.7	.....	.....	62.2	0.804
4500	446.0	594.8	− 2.7	270.3	.....	.....	59.2	0.765
5000	.....	.....	− 6.8	266.2	.....	.....	.....	.....
6000	.....	.....	−16.2	256.8	.....	.....	.....	.....

September.

0	762.6	1016.8	22.5	295.5	15.21	21.28	92.0	1.190
500	721.0	961.3	19.2	292.2	12.68	17.91	88.0	1.138
526	718.5	958.0	19.0	292.0	12.52	16.70	87.8	1.135
1000	679.8	906.4	16.1	289.1	10.16	13.54	84.0	1.086
1500	641.5	855.3	13.5	286.5	8.47	11.29	80.3	1.038
2000	604.1	805.4	11.4	284.4	5.76	7.68	76.0	0.983
2500	569.0	758.7	9.0	282.0	4.82	6.43	72.2	0.934
3000	535.8	714.4	6.2	279.2	3.98	5.31	68.7	0.889
3500	504.4	672.5	3.1	276.1	.....	.....	65.5	0.846
4000	474.7	633.0	− 0.2	272.8	.....	.....	62.4	0.806
4500	444.9	593.3	− 3.7	269.3	.....	.....	59.2	0.766
5000	417.4	556.6	− 6.6	266.4	.....	.....	56.2	0.726
6000	.....	.....	−11.1	261.9	.....	.....	.....	.....

*Based on few observations; figures not regarded as reliable.

TABLE 1.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va.*—Continued.

October.

Altitudes above M. S. L.	Pressures.		Temperatures.		Vapor pressures.		Densities.	
m.	*mm.*	*mb.*	°*C.*	°*A.*	*mm.*	*mb.*	%	*kg./cu. m.*
0	761.2	1014.9	14.8	287.8	9.68	13.91	94.5	1.222
500	720.3	960.4	11.9	284.9	8.30	12.07	90.4	1.169
526	717.5	956.6	11.7	284.7	8.25	11.00	90.1	1.166
1000	677.9	903.8	9.0	282.0	6.98	9.30	86.0	1.112
1500	640.5	854.0	7.1	280.1	5.83	7.77	81.9	1.058
2000	600.7	800.9	5.5	278.5	4.67	6.23	77.2	0.999
2500	565.0	753.3	3.5	276.5	4.65	6.20	73.2	0.946
3000	531.4	708.5	1.0	274.0	3.20	4.27	69.5	0.899
3500	498.7	664.9	− 1.9	271.1	.....	.....	66.1	0.854
4000	469.0	625.4	− 4.7	268.3	.....	.....	62.7	0.811
4500	439.7	586.4	− 7.5	265.5	.....	.....	59.4	0.768
5000	411.4	548.6	−10.9	262.1	.....	.....	56.3	0.728
6000	*369.3	*492.5	−17.2	255.8	.....	.....	*51.8	*0.670
7000	.....	.....	−26.0	247.0	.....	.....	.....	.....

November.

0	762.0	1016.0	7.9	280.9	4.24	5.65	97.2	1.257
500	718.9	958.5	5.2	278.2	3.60	4.80	92.6	1.198
526	716.1	954.8	5.1	278.1	3.56	4.75	92.3	1.194
1000	675.6	900.8	2.8	275.8	2.97	3.96	87.8	1.136
1500	634.9	846.5	0.7	273.7	2.36	3.15	83.2	1.076
2000	596.5	795.3	− 0.9	272.1	2.00	2.66	78.6	1.017
2500	560.1	746.8	− 2.9	270.1	1.70	2.26	74.4	0.962
3000	526.1	701.5	− 5.5	267.5	1.67	2.23	70.6	0.912
3500	493.5	658.0	− 8.3	264.7	.....	.....	66.9	0.865
4000	464.8	619.8	−11.4	261.6	.....	.....	63.8	0.825
4500	435.6	580.9	−14.5	258.5	.....	.....	60.5	0.783
5000	408.1	544.2	−17.5	255.5	.....	.....	57.4	0.742
6000	.....	.....	−23.0	250.0	.....	.....	.....	.....

December.

0	762.2	1016.2	2.0	275.0	4.18	5.57	99.4	1.285
500	718.2	957.6	− 0.2	272.8	4.07	5.43	94.4	1.220
526	715.9	954.5	− 0.3	272.7	4.07	5.43	94.1	1.217
1000	674.5	899.3	− 1.9	271.1	3.92	5.23	89.2	1.153
1500	633.2	844.2	− 2.6	270.4	3.58	4.77	83.9	1.085
2000	594.4	792.5	− 3.7	269.3	3.09	4.12	79.1	1.023
2500	557.8	743.7	− 5.6	267.4	2.40	3.20	74.8	0.967
3000	522.9	697.2	− 8.1	264.9	1.66	2.21	70.8	0.916
3500	491.3	655.1	−10.9	262.1	.....	.....	67.3	0.870
4000	460.8	614.5	−13.6	259.4	.....	.....	63.7	0.824
4500	431.4	575.3	−16.7	256.3	.....	.....	60.4	0.781
5000	*397.5	*530.1	−19.4	253.6	.....	.....	*56.3	*0.727

Spring.

0	760.0	1013.3	14.0	287.0	7.91	10.55	94.7	1.225
500	718.1	957.4	10.8	283.8	6.62	8.83	90.6	1.171
526	716.2	954.9	10.7	283.7	6.56	8.75	90.4	1.170
1000	676.5	902.0	7.8	280.8	5.39	7.19	86.3	1.116
1500	636.6	848.8	5.2	278.2	4.25	5.66	82.0	1.060
2000	598.7	798.2	2.6	275.6	3.26	4.35	77.9	1.007
2500	562.7	750.3	0.0	273.0	2.39	3.18	73.9	0.956
3000	528.9	705.2	− 2.8	270.2	1.78	2.37	70.2	0.908
3500	497.0	662.7	− 5.8	267.2	.....	.....	66.7	0.863
4000	466.0	621.3	− 8.8	264.2	.....	.....	63.3	0.819
4500	436.1	581.5	−12.1	260.9	.....	.....	60.0	0.776
5000	408.8	545.1	−15.5	257.5	.....	.....	57.0	0.737
6000	*357.8	*477.1	−22.1	250.9	.....	.....	*51.2	*0.662
7000	.....	.....	−28.4	244.6	.....	.....	.....	.....

Summer.

0	758.9	1011.8	25.0	298.0	17.14	22.85	90.7	1.173
500	718.0	957.3	21.6	294.6	13.76	18.35	86.9	1.124
526	716.7	955.6	21.4	294.4	13.58	18.10	86.8	1.123
1000	678.5	904.6	18.2	291.2	10.66	14.21	83.2	1.076
1500	639.9	853.2	15.1	288.1	8.24	10.98	79.4	1.027
2000	603.0	804.0	12.1	285.1	6.14	8.19	75.7	0.979
2500	568.0	757.3	9.3	282.3	4.31	5.74	72.1	0.932
3000	534.9	713.2	6.4	279.4	3.10	4.13	68.6	0.887
3500	503.3	671.1	3.2	276.2	.....	.....	65.3	0.845
4000	473.5	631.3	− 0.1	272.9	.....	.....	62.2	0.805
4500	444.5	592.7	− 3.4	269.6	.....	.....	59.2	0.765
5000	417.2	556.3	− 6.4	266.6	.....	.....	56.2	0.726
6000	*372.0	*496.0	−13.5	259.5	.....	.....	*51.5	*0.666
7000	.....	.....	−19.3	253.7	.....	.....	.....	.....

*Based on few observations; figures not regarded as reliable.

TABLE 1.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va.*—Continued.

Fall.

Altitudes above M. S. L.	Pressures.		Temperatures.		Vapor pressures.		Densities.	
m.	*mm.*	*mb.*	°*C.*	°*A.*	*mm.*	*mb.*	%	*kg./cu.m.*
0	762.0	1016.0	15.1	288.1	9.03	12.04	94.6	1.223
500	720.0	960.0	12.1	285.1	7.65	10.20	90.4	1.168
526	717.4	956.5	12.0	285.0	7.58	10.10	90.1	1.164
1000	677.8	903.7	9.4	282.4	6.28	8.37	85.9	1.111
1500	639.0	852.0	7.3	280.3	5.14	6.85	81.6	1.056
2000	600.4	800.5	5.6	278.6	4.03	5.37	77.2	0.998
2500	564.7	752.9	3.5	276.5	3.59	4.79	72.9	0.943
3000	531.1	708.1	0.9	273.9	3.08	4.11	69.5	0.898
3500	498.9	655.2	− 2.0	271.0	.....	.....	66.0	0.854
4000	469.5	626.0	− 5.0	268.0	.....	.....	62.8	0.813
4500	440.1	586.8	− 8.1	264.9	.....	.....	59.6	0.771
5000	412.3	549.7	−11.2	261.8	.....	.....	56.5	0.731
6000	*369.3	*492.4	−17.1	255.9	.....	.....	*51.8	*0.670
7000	.....	.....	−27.4	245.6	.....	.....	.....	.....

Winter.

0	765.0	1020.0	0.7	273.7	3.18	4.24	100.2	1.296
500	720.0	960.0	− 0.7	272.3	2.89	3.85	94.8	1.226
526	718.0	957.3	− 0.8	272.2	2.87	3.83	94.6	1.223
1000	674.6	899.4	− 2.1	270.9	2.54	3.39	89.3	1.155
1500	633.6	844.8	− 3.0	270.0	2.24	2.99	84.2	1.089
2000	594.4	792.5	− 4.2	268.8	2.03	2.71	79.3	1.026
2500	558.3	744.4	− 6.0	267.0	1.58	2.10	75.0	0.970
3000	523.6	698.1	− 8.4	264.6	1.21	1.61	71.0	0 918
3500	491.6	655.5	−11.2	261.8	.....	.....	67.4	0.871
4000	462.0	616.0	−13.9	259.1	.....	.....	64.0	0.828
4500	435.3	580.4	−16.8	256.2	.....	.....	61.0	0.789
5000	*397.5	*530.0	−19.7	253.3	.....	.....	*56.3	*0.728

Year.

0	760.0	1013.3	13.7	286.7	8.62	11.49	94.8	1.226
500	718.5	958.0	11.0	284.0	7.23	9.64	90.5	1.171
526	716.6	955.4	10.9	283.9	7.14	9.52	90.3	1.168
1000	676.8	902.4	8.4	281.4	5.87	7.82	86.1	1.113
1500	637.3	849.7	6.2	279.2	4.55	6.07	81.8	1.057
2000	599.2	798.9	4.0	277.0	3.60	4.80	77.5	1.002
2500	563.4	751.2	1.7	274.7	2.80	3.73	73.5	0.951
3000	529.6	706.1	− 1.0	272.0	2.15	2.87	69.8	0.903
3500	497.7	663.6	− 4.0	269.0	.....	.....	66.4	0.858
4000	467.8	623.7	− 7.0	266.0	.....	.....	63.1	0.816
4500	439.0	585.3	−10.2	262.8	.....	.....	60.0	0.775
5000	409.0	545.3	−13.3	259.7	.....	.....	56.6	0.731
6000	*366.4	*488.5	−19.8	253.2	.....	.....	*52.0	*0.672
7000	.....	.....	−27.1	245.9	.....	.....	.....	.....

*Based on few observations; figures not regarded as reliable.

TABLE 2.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va. (English measures).*

January.

Altitudes above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	°*F.*	*Inches.*	%	*Lbs./cu. ft.*
0	29.97	31.6	0.08	100.2	0.0808
1000	28.96	30.4	.08	97.0	.0783
2000	27.94	29.5	.08	93.8	.0757
3000	26.92	28.6	.08	90.5	.0730
4000	25.90	27.7	.08	87.2	.0704
5000	24.93	26.6	.07	84.1	.0679
6000	23.99	25.5	0.07	81.2	0.0655
7000	23.08	24.1	.06	78.3	.0632
8000	22.20	22.3	.06	75.6	.0610
9000	21.34	19.6	.05	73.1	.0590
10000	20.50	16.7	.04	70.6	.0570
11000	19.71	13.8	.....	68.3	0.0552
12000	18.96	10.9	.....	66.2	.0534
13000	18.28	7.9	.....	64.2	.0518
14000	*17.71	5.0	.....	*62.6	*.0505
15000	.....	1.8	.....	.....	.....
16000	.....	−1.5	.....	.....	.....
17000	.....	−4.9	.....	.....	.....
18000	.....	−8.1	.....	.....	.....

*Based on few observations; figures not regarded as reliable.

TABLE 2.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va. (English measures)*—Con.

February.

Altitudes above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	°*F.*	*Inches.*	%	*Lbs./cu. ft.*
0	30.00	34.0	0.13	99.7	0.0805
1000	28.94	32.0	.11	96.6	.0780
2000	27.87	30.0	.09	93.4	.0754
3000	26.84	28.2	.08	90.3	.0729
4000	25.82	26.8	.07	87.1	.0703
5000	24.84	25.7	.07	84.0	.0678
6000	23.91	24.3	0.06	81.1	0.0655
7000	23.02	22.5	.05	78.4	.0633
8000	22.16	20.5	.04	75.8	.0612
9000	21.30	18.0	.03	73.2	.0591
10000	20.48	15.3	.03	70.8	.0572
11000	19.70	12.2	.....	68.6	0.0554
12000	18.98	9.0	.....	66.5	.0537
13000	18.30	5.7	.....	64.6	.0522
14000	17.63	2.5	.....	62.7	.0506
15000	.....	−0.9	.....	.....	.....
16000	.....	−4.5	.....	.....	.....
17000	.....	−8.3	.....	.....	.....

March.

0	29.99	44.4	0.19	97.5	0.0787
1000	28.97	41.9	.18	94.7	.0764
2000	27.92	39.6	.16	91.7	.0740
3000	26.91	37.2	.14	88.8	.0717
4000	25.90	35.1	.12	85.9	.0693
5000	24.92	32.9	.11	83.0	.0670
6000	23.98	30.9	0.09	80.2	0.0648
7000	23.09	28.6	.08	77.6	.0626
8000	22.24	26.1	.06	75.2	.0607
9000	21.41	23.4	.05	72.8	.0587
10000	20.63	20.5	.03	70.6	.0570
11000	19.87	17.4	.....	68.4	0.0552
12000	19.10	14.4	.....	66.2	.0534
13000	18.35	11.1	.....	64.1	.0517
14000	17.67	7.7	.....	62.2	.0502
15000	17.06	4.1	.....	60.5	.0488
16000	16.54	0.9	.....	59.0	0.0476
17000	.....	−2.4	.....	.....	.....

April.

0	29.96	57.0	0.31	94.9	0.0766
1000	28.94	53.2	.28	92.4	.0746
2000	27.94	49.6	.25	89.9	.0725
3000	26.94	46.2	.22	87.2	.0704
4000	25.95	43.2	.20	84.5	.0682
5000	24.99	39.9	.18	82.0	.0662
6000	24.07	36.7	0.15	79.5	0.0642
7000	23.18	33.6	.14	77.1	.0622
8000	22.33	30.7	.12	74.7	.0603
9000	21.50	27.9	.10	72.3	.0584
10000	20.71	25.0	.08	70.2	.0567
11000	19.92	21.6	.....	67.9	0.0548
12000	19.17	18.3	.....	65.8	.0532
13000	18.38	14.9	.....	63.6	.0513
14000	17.65	11.5	.....	61.5	.0496
15000	16.94	7.9	.....	59.5	.0480
16000	16.26	4.5	.....	57.6	0.0465
17000	15.58	1.0	.....	55.6	.0449
18000	14.95	− 2.6	.....	53.8	.0434
19000	*14.56	− 6.3	.....	*52.8	*.0426
20000	.....	−10.1	.....	.....	.....
21000	.....	−13.9	.....	.....	.....
22000	.....	−17.7	.....	.....	.....
23000	.....	−20.9	.....	.....	.....

* Based on few observations; figures not regarded as reliable.

TABLE 2.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va. (English measures)*—Con.

May.

Altitudes above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	*°F.*	*Inches.*	*%*	*Lbs./cu. ft.*
0	29.93	69.6	0.45	92.4	0.0746
1000	28.94	65.5	.40	90.1	.0727
2000	27.95	61.3	.38	87.7	.0708
3000	26.96	57.2	.31	85.3	.0689
4000	26.00	53.2	.26	83.0	.0670
5000	25.07	49.5	.22	80.6	.0651
6000	24.17	45.9	0.18	78.3	0.0632
7000	23.30	42.4	.15	76.1	.0614
8000	22.44	39.0	.12	73.8	.0596
9000	21.61	35.6	.10	71.6	.0578
10000	20.83	32.4	.09	69.5	.0561
11000	20.05	28.9	.....	67.3	0.0544
12000	19.29	25.7	.....	65.2	.0527
13000	18.54	22.3	.....	63.1	.0510
14000	17.80	18.7	.....	61.1	.0493
15000	17.08	14.5	.....	59.2	.0478
16000	16.35	10.2	.....	57.1	0.0461
17000	15.57	5.9	.....	55.0	.0444
18000	14.91	2.3	.....	53.0	.0428
19000	14.29	− 0.9	.....	51.2	.0413
20000	.....	− 4.0	.....	.....	.....
21000	.....	− 7.2	.....	.....	.....
22000	.....	−10.5	.....	.....	.....
23000	.....	−13.2	.....	.....	.....

June.

0	29.88	73.8	0.56	91.4	0.0738
1000	28.90	70.2	.51	89.0	.0719
2000	27.92	66.6	.45	86.6	.0699
3000	26.94	63.0	.40	84.2	.0680
4000	26.01	59.5	.34	81.9	.0661
5000	25.09	56.5	.29	79.6	.0642
6000	24.20	53.2	0.24	77.3	0.0624
7000	23.31	50.0	.20	75.0	.0605
8000	22.49	47.1	.17	72.8	.0587
9000	21.66	43.9	.14	70.5	.0569
10000	20.88	40.6	.12	68.5	.0553
11000	20.12	37.2	.....	66.4	0.0536
12000	19.39	33.6	.....	64.5	.0521
13000	18.65	29.8	.....	62.5	.0505
14000	17.97	26.1	.....	60.7	.0490
15000	17.32	22.5	.....	59.0	.0476
16000	16.67	19.4	.....	57.1	0.0461
17000	16.06	16.3	.....	55.4	.0448
18000	15.48	13.1	.....	53.8	.0434

July.

0	29.88	80.0	0.67	90.2	0.0728
1000	28.90	75.9	.59	88.0	.0710
2000	27.90	72.0	.52	85.6	.0691
3000	26.96	67.8	.45	83.5	.0674
4000	26.05	64.0	.39	81.3	.0656
5000	25.15	60.4	.33	79.1	.0638
6000	24.26	56.8	0.28	76.8	0.0620
7000	23.39	53.4	.23	74.6	.0602
8000	22.56	50.2	.19	72.4	.0585
9000	21.73	46.9	.15	70.3	.0567
10000	20.95	43.7	.12	68.2	.0551
11000	20.20	40.1	.....	66.3	0.0535
12000	19.47	36.3	.....	64.4	.0520
13000	18.74	32.5	.....	62.5	.0504
14000	18.03	28.9	.....	60.6	.0489
15000	17.34	25.3	.....	58.7	.0474
16000	16.71	22.1	.....	57.0	0.0460
17000	16.14	18.9	.....	55.4	.0447
18000	15.67	15.6	.....	54.2	.0437
19000	* 15.08	12.6	.....	* 52.5	* .0424
20000	.....	9.3	.....	.....	.....
21000	.....	6.1	.....	.....	.....
22000	.....	2.8	.....	.....	.....
23000	.....	−0.2	.....	.....	.....

* Based on few observations; figures not regarded as reliable.

TABLE 2.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va. (English measures)*—Con.

August.

Altitudes above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	*°F.*	*Inches.*	*%*	*Lbs./cu. ft.*
0	30.01	77.4	0.81	90.9	0.0734
1000	29.02	73.6	.69	88.6	.0715
2000	27.99	69.6	.58	86.2	.0696
3000	27.01	66.0	.48	83.9	.0677
4000	26.07	62.6	.40	81.5	.0658
5000	25.16	59.4	.34	79.2	.0640
6000	24.28	56.3	0.29	77.0	0.0621
7000	23.42	53.2	.24	74.7	.0603
8000	22.59	50.4	.20	72.5	.0585
9000	21.77	47.1	.16	70.4	.0568
10000	20.98	43.7	.13	68.3	.0552
11000	20.22	40.3	.....	66.3	0.0535
12000	19.48	37.0	.....	64.3	.0519
13000	18.78	33.8	.....	62.4	.0504
14000	18.11	30.0	.....	60.7	.0490
15000	.....	26.1	.....	.....	.....
16000	.....	21.6	.....	.....	.....
17000	.....	16.9	.....	.....	.....
18000	.....	12.0	.....	.....	.....
19000	.....	6.8	.....	.....	.....

September.

0	30.02	72.5	0.60	92.0	0.0742
1000	29.04	68.7	.54	89.7	.0724
2000	28.03	65.1	.48	87.2	.0704
3000	27.07	61.9	.42	84.8	.0684
4000	26.12	59.0	.35	82.3	.0665
5000	25.20	56.3	.30	79.9	.0645
6000	24.30	54.0	0.25	77.4	0.0625
7000	23.41	51.4	.19	75.0	.0606
8000	22.56	48.9	.17	72.7	.0587
9000	21.75	45.9	.15	70.5	.0569
10000	20.97	42.6	.14	68.4	.0552
11000	20.21	39.2	.....	66.4	0.0536
12000	19.50	35.8	.....	64.5	.0521
13000	18.78	32.2	.....	62.6	.0505
14000	18.06	28.4	.....	60.7	.0490
15000	17.37	24.3	.....	58.9	.0475
16000	16.70	20.8	.....	57.0	0.0460
17000	.....	19.2	.....	.....	.....
18000	.....	17.4	.....	.....	.....
19000	.....	15.6	.....	.....	.....
20000	.....	10.4	.....	.....	.....
21000	.....	4.3	.....	.....	.....
22000	.....	−3.3	.....	.....	.....

October.

0	29.97	58.6	0.38	94.6	0.0763
1000	29.00	55.4	.35	92.1	.0744
2000	28.00	52.2	.31	89.5	.0722
3000	27.01	49.1	.28	86.9	.0701
4000	26.06	46.6	.26	84.3	.0680
5000	25.15	44.6	.22	81.7	.0660
6000	24.23	42.8	0.20	79.0	0.0638
7000	23.31	41.0	.17	76.3	.0616
8000	22.44	38.8	.16	73.8	.0596
9000	21.59	36.3	.14	71.4	.0576
10000	20.79	33.4	.13	69.1	.0558
11000	20.01	30.2	.....	67.0	0.0541
12000	19.26	27.0	.....	64.9	.0524
13000	18.55	23.9	.....	62.8	.0507
14000	17.85	21.0	.....	60.8	.0491
15000	17.15	17.8	.....	58.9	.0475
16000	16.45	14.0	.....	56.9	0.0459
17000	15.83	10.0	.....	55.2	.0446
18000	15.24	6.6	.....	53.6	.0432
19000	* 14.80	3.4	.....	* 52.4	* .0423
20000	.....	−0.2	.....	.....	.....
21000	.....	−4.2	.....	.....	.....
22000	.....	−8.9	.....	.....	.....
23000	.....	−14.8	.....	.....	.....

* Based on few observations; figures not regarded as reliable.

TABLE 2.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va. (English measures)*—Con.

November.

Altitudes above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	*°F.*	*Inches.*	%	*Lbs./cu. ft.*
0	30.00	46.2	0.17	97.3	0.0785
1000	28.98	43.2	.15	94.5	.0763
2000	27.94	40.3	.13	91.7	.0740
3000	26.90	37.8	.12	88.7	.0716
4000	25.92	35.2	.11	85.9	.0694
5000	24.96	33.1	.09	83.1	.0671
6000	24.04	31.3	0.08	80.4	0.0649
7000	23.11	29.5	.07	77.5	.0626
8000	22.24	27.3	.07	74.9	.0605
9000	21.38	24.6	.06	72.5	.0585
10000	20.50	21.7	.06	70.2	.0567
11000	19.82	18.5	.....	68.0	0.0549
12000	19.09	15.4	.....	66.0	.0532
13000	18.38	12.0	.....	64.0	.0517
14000	17.68	8.6	.....	62.0	.0501
15000	17.00	5.2	.....	60.1	.0485
16000	16.33	1.9	.....	58.1	0.0469
17000	15.70	−1.1	.....	56.3	.0454
18000	15.09	−4.0	.....	54.4	.0439
19000	.....	−7.2	.....	.....	.....

December.

0	30.01	35.6	0.16	99.4	0.0802
1000	28.96	33.3	.16	96.3	.0778
2000	27.90	30.9	.16	93.3	.0753
3000	26.85	28.9	.16	90.1	.0728
4000	25.85	27.9	.15	86.9	.0702
5000	24.87	27.1	.14	83.8	.0676
6000	23.93	26.1	0.13	80.8	0.0652
7000	23.00	24.6	.11	77.9	.0629
8000	22.13	22.5	.10	75.3	.0608
9000	21.29	19.8	.08	72.9	.0588
10000	20.49	16.9	.07	70.6	.0570
11000	19.72	13.8	.....	68.4	0.0552
12000	18.98	10.9	.....	66.2	.0534
13000	18.24	7.9	.....	64.0	.0517
14000	17.53	4.6	.....	62.0	.0500
15000	16.81	1.2	.....	59.9	.0483
16000	* 16.01	−1.8	.....	* 57.4	* 0.0463

Spring.

0	29.92	57.2	0.31	94.7	0.0765
1000	28.93	53.8	.28	92.2	.0744
2000	27.92	50.4	.25	89.7	.0724
3000	26.93	46.9	.22	87.1	.0703
4000	25.96	43.9	.19	84.5	.0682
5000	25.00	41.0	.17	81.9	.0661
6000	24.09	38.3	0.14	79.3	0.0640
7000	23.19	35.4	.12	76.8	.0620
8000	22.33	32.5	.10	74.4	.0601
9000	21.51	29.5	.08	72.2	.0582
10000	20.72	26.4	.06	70.0	.0565
11000	19.95	23.0	.....	67.9	0.0548
12000	19.20	19.8	.....	65.7	.0531
13000	18.46	16.5	.....	63.7	.0514
14000	17.76	13.1	.....	61.7	.0498
15000	17.04	9.3	.....	59.7	.0482
16000	16.34	5.5	.....	57.7	0.0466
17000	15.65	1.8	.....	55.7	.0450
18000	15.02	− 1.8	.....	53.9	.0435
19000	* 14.40	− 5.4	.....	* 52.1	* .0420
20000	.....	− 8.9	.....	.....	.....
21000	.....	−12.5	.....	.....	.....
22000	.....	−15.9	.....	.....	.....
23000	.....	−19.1	.....	.....	.....

* Based on few observations; figures not regarded as reliable.

TABLE 2.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va. (English measures)*—Con.

Summer.

Altitudes above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	*°F.*	*Inches.*	%	*Lbs./cu. ft.*
0	29.88	77.0	0.68	90.7	0.0732
1000	28.90	73.2	.59	88.4	.0714
2000	27.92	69.4	.51	86.1	.0695
3000	26.98	65.7	.44	83.8	.0677
4000	26.06	62.2	.38	81.6	.0659
5000	25.15	58.8	.32	79.3	.0640
6000	24.25	55.6	0.27	77.0	0.0622
7000	23.37	52.3	.22	74.7	.0603
8000	22.55	49.3	.18	72.6	.0586
9000	21.73	46.2	.15	70.4	.0568
10000	20.94	42.8	.12	68.3	.0552
11000	20.19	39.4	.....	66.3	0.0536
12000	19.45	35.8	.....	64.4	.0520
13000	18.73	32.2	.....	62.5	.0504
14000	18.03	28.6	.....	60.6	.0489
15000	17.32	25.0	.....	58.7	.0474
16000	16.69	21.9	.....	56.9	0.0459
17000	16.09	18.3	.....	55.3	.0446
18000	15.55	14.5	.....	53.9	.0435
19000	* 14.99	10.6	.....	* 52.4	* .0423
20000	.....	6.6	.....	.....	.....
21000	.....	3.2	.....	.....	.....
22000	.....	0.0	.....	.....	.....
23000	.....	− 2.9	.....	.....	.....

Fall.

0	30.00	59.2	0.36	94.6	0.0763
1000	29.01	55.9	.32	92.1	.0743
2000	27.99	52.7	.29	89.4	.0722
3000	27.02	49.6	.26	86.9	.0701
4000	26.06	47.1	.23	84.2	.0680
5000	25.10	45.0	.20	81.5	.0658
6000	24.17	43.2	0.17	78.8	0.0636
7000	23.27	41.0	.15	76.2	.0615
8000	22.41	38.8	.14	73.7	.0595
9000	21.58	36.1	.13	71.4	.0576
10000	20.79	33.1	.12	69.2	.0558
11000	20.04	29.8	.....	67.1	0.0542
12000	19.31	26.6	.....	65.2	.0526
13000	18.59	23.4	.....	63.1	.0510
14000	17.87	19.9	.....	61.2	.0494
15000	17.16	16.5	.....	59.2	.0478
16000	16.52	13.1	.....	57.4	0.0463
17000	15.90	9.9	.....	55.6	.0449
18000	15.37	6.6	.....	54.1	.0437
19000	* 14.87	3.4	.....	* 52.8	* .0426

Winter.

0	30.12	33.3	0.13	100.2	0.0809
1000	29.05	31.6	.12	97.0	.0783
2000	27.94	30.2	.11	93.6	.0756
3000	26.86	28.6	.10	90.3	.0729
4000	25.85	27.5	.09	87.1	.0703
5000	24.87	26.6	.09	83.9	.0678
6000	23.93	25.3	0.08	81.0	0.0654
7000	23.02	23.7	.07	78.2	.0631
8000	22.16	21.6	.06	75.6	.0610
9000	21.31	19.2	.06	73.1	.0590
10000	20.51	16.3	.05	70.7	.0571
11000	19.72	13.3	.....	68.4	0.0552
12000	18.99	10.2	.....	66.3	.0536
13000	18.31	7.3	.....	64.4	.0520
14000	17.65	4.3	.....	62.5	.0504
15000	16.93	1.0	.....	60.4	.0487
16000	* 16.02	−2.2	.....	* 57.5	* 0.0464
17000	.....	−5.6	.....	.....	.....
18000	.....	−9.0	.....	.....	.....

*Based on few observations; figures not regarded as reliable.

TABLE 2.—*Mean free-air pressures, temperatures, vapor pressures, and densities, as observed at Mount Weather, Va. (English measures)*—Con.

Year.

Altitudes above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	*° F.*	*Inches.*	*%*	*Lbs./cu. ft.*
0	29.92	56.7	0.34	94.8	0.0765
1000	28.93	53.8	.31	92.2	.0744
2000	27.94	50.9	.27	89.6	.0723
3000	26.94	47.8	.24	86.9	.0702
4000	25.95	45.3	.21	84.2	.0680
5000	25.00	43.0	.18	81.5	.0658
6000	24.09	40.6	0.15	78.9	0.0637
7000	23.21	38.1	.13	76.5	.0617
8000	22.36	35.6	.11	74.1	.0598
9000	21.54	32.7	.10	71.8	.0579
10000	20.75	29.7	.08	69.6	.0562
11000	19.97	26.4	.....	67.4	0.0544
12000	19.25	23.0	.....	65.5	.0528
13000	18.51	19.8	.....	63.4	.0512
14000	17.82	16.3	.....	61.5	.0496
15000	17.11	12.7	.....	59.5	.0480
16000	16.40	9.3	.....	57.4	0.0464
17000	15.77	5.9	.....	55.7	.0449
18000	15.24	2.5	.....	54.2	.0438
19000	* 14.76	− 1.1	.....	* 52.9	* .0427
20000	.....	− 4.9	.....	.....	.....
21000	.....	− 8.9	.....	.....	.....
22000	.....	−12.8	.....	.....	.....
23000	.....	−17.0	.....	.....	.....

* Based on few observations; figures not regarded as reliable.

TABLE 3.—*Mean values of atmospheric pressures, temperatures, vapor pressures, and densities, based on sounding balloon observations at Fort Omaha, Nebr.; Indianapolis, Ind.; Huron, S. Dak.; and Avalon, Cal.*

Spring.

Altitude above M. S. L.	Pressures.		Temperatures.		Vapor pressures.		Densities.	
m.	*mm.*	*mb.*	*° C.*	*° A.*	*mm.*	*mb.*	*%*	*kg./cu. m.*
0	757	1009	16.9	289.9	9.45	12.60	93.4	1.207
500	716	955	13.9	286.9	7.71	10.28	89.3	1.154
1000	674	899	9.7	282.7	5.93	7.91	85.5	1.105
2000	597	796	5.0	278.0	3.93	5.25	77.0	0.995
3000	527	703	0.9	273.9	2.70	3.60	69.0	.892
4000	465	620	− 5.1	267.9	1.68	2.25	62.3	.805
5000	409	545	−12.4	260.6	0.75	1.01	56.6	.732
6000	357	476	−17.2	255.8	0.42	0.56	50.1	0.648
7000	311	415	−24.5	248.5	.18	.24	44.9	.581
8000	270	360	−35.2	237.8	.10	.133	40.8	.527
9000	233	311	−43.4	229.6	.026	.035	36.4	.471
10000	201	268	−50.4	222.6	.010	.013	32.4	.419
11000	172	229	−53.8	219.2	0.006	0.008	28.2	0.364
12000	148	197	−54.8	218.2	.004	.005	24.4	.315
13000	127	169	−55.2	217.8	.004	.005	21.0	.271
14000	109	145	−55.4	217.6	.004	.005	18.0	.233
15000	95	127	−55.2	217.8	.005	.007	15.7	.203
16000	81	108	−56.3	216.7	0.004	0.005	13.4	0.174
17000	69	92	−57.8	215.2	.003	.004	11.5	.149
18000	59	79	.....	.....	.....	.....	.....	.....
19000	50	67	.....	.....	.....	.....	.....	.....
20000	43	57	.....	.....	.....	.....	.....	.....
21000	37	49	.....	.....	.....	.....	.....	.....
22000	32	43	.....	.....	.....	.....	.....	.....
23000	27	36	.....	.....	.....	.....	.....	.....
24000	23	31	.....	.....	.....	.....	.....	.....
25000	19	25	.....	.....	.....	.....	.....	.....

TABLE 3.—*Mean values of atmospheric pressures, temperatures, vapor pressures, and densities, based on sounding balloon observations at Fort Omaha, Nebr.; Indianapolis, Ind.; Huron, S. Dak.; and Avalon, Cal.*—Continued.

Summer.

Altitude above M. S. L.	Pressures.		Temperatures.		Vapor pressures.		Densities.	
m.	*mm.*	*mb.*	*° C.*	*° A.*	*mm.*	*mb.*	*%*	*kg./cu. m.*
0	761	1015	24.9	297.9	14.94	19.92	91.1	1.177
500	719	959	23.2	296.2	11.90	15.87	86.6	1.120
1000	679	905	21.6	294.6	9.35	12.47	82.4	1.065
2000	604	805	16.6	289.6	5.78	7.70	74.6	0.965
3000	536	715	10.3	283.3	3.58	4.77	67.8	.876
4000	475	633	3.9	276.9	2.22	2.96	61.5	.795
5000	419	559	− 2.5	270.5	1.30	1.74	55.6	.718
6000	369	492	− 8.5	264.5	0.73	0.97	50.1	0.647
7000	324	432	−14.3	258.7	.45	.60	45.0	.581
8000	284	379	−20.9	252.1	.260	.346	40.4	.523
9000	248	331	−27.2	245.8	.142	.190	36.2	.468
10000	215	287	−33.9	239.1	.073	.097	32.3	.418
11000	187	249	−40.5	232.5	0.032	0.042	28.9	0.374
12000	161	215	−46.8	226.2	.014	.019	25.6	.331
13000	139	185	−50.0	223.0	.008	.011	22.4	.290
14000	119	159	−53.6	219.4	.005	.007	19.5	.252
15000	102	136	−56.1	216.9	.003	.004	16.9	.218
16000	88	117	−58.0	215.0	0.002	0.003	14.7	0.190
17000	75	100	−57.3	215.7	.003	.004	12.5	.162
18000	64	85	−55.5	217.5	.004	.005	10.6	.137
19000	55	73	−53.2	219.8	.006	.008	9.0	.116
20000	47	63	−51.1	221.9	.008	.011	7.6	.098
21000	41	55	−49.4	223.6	0.009	0.012	6.6	0.085
22000	35	47	−48.3	224.7	.011	.015	5.6	.072
23000	30	40	−45.7	227.3	.015	.020	4.7	.061
24000	27	36	−41.9	231.1	.022	.029	4.2	.054
25000	23	31	−39.7	233.3	.027	.036	3.5	.048
26000	19	25	−38.5	234.5	0.026	0.034	2.9	0.038
27000	16	21	−40.4	232.6	.022	.029	2.5	.032
28000	15	20	−37.0	236.0	.038	.050	2.3	.030
29000	14	19	−35.4	237.6	.041	.055	2.1	.027
30000	12	16	−34.8	238.2	.046	.061	1.8	.023
31000	11	15	−34.0	239.0	0.051	0.068	1.6	0.021
32000	10	13	−41.9	231.1	.004	.005	1.5	.020

Fall.

0	759	1012	23.8	296.8	11.00	14.67	91.4	1.182
500	719	959	19.5	292.5	9.00	12.00	87.9	1.136
1000	678	904	14.9	287.9	7.28	9.71	84.2	1.089
2000	603	804	10.2	283.2	5.00	6.66	76.2	0.986
3000	532	709	3.8	276.8	2.99	3.99	69.0	.893
4000	468	624	− 3.1	269.9	1.69	2.25	62.2	.804
5000	413	551	− 9.9	263.1	0.97	1.29	56.4	.729
6000	362	483	−17.1	255.9	0.52	0.70	50.8	0.657
7000	317	423	−23.4	249.6	.29	.39	45.6	.590
8000	276	368	−30.6	242.4	.142	.189	40.9	.529
9000	240	320	−37.3	235.7	.066	.088	36.6	.473
10000	207	276	−43.7	229.3	.029	.039	32.4	.419
11000	178	237	−50.3	222.7	0.015	0.020	28.4	0.367
12000	153	204	−52.2	220.8	.010	.013	24.9	.322
13000	131	175	−53.9	219.1	.008	.010	21.5	.278
14000	113	151	−54.3	218.7	.007	.009	18.6	.240
15000	95	127	−55.5	217.5	.006	.008	15.7	.203
16000	82	109	−55.4	217.6	0.006	0.008	13.5	0.175
17000	70	93	−55.0	218.0	.005	.007	11.5	.149
18000	60	80	−53.5	219.5	.006	.008	9.8	.127
19000	52	69	−51.0	222.0	.008	.011	8.4	.109
20000	45	60	−47.2	225.8	.014	.018	7.2	.093
21000	39	52	−44.6	228.4	0.019	0.025	6.1	0.079
22000	34	45	−42.5	230.5	.026	.034	5.3	.068
23000	29	39	−39.9	233.1	.042	.056	4.5	.058
24000	25	33	−37.2	235.8	.075	.100	3.8	.049
25000	22	29	−42.2	230.8	.002	.003	3.4	.044
26000	19	25	−40.2	232.8	0.002	0.003	2.9	0.038
27000	17	23	−39.7	233.3	.002	.003	2.6	.034
28000	14	19	−40.1	232.9	.002	.003	2.2	.028
29000	12	16	−40.5	232.5	.002	.003	1.8	.024
30000	10	13	−40.8	232.2	.002	.003	1.6	.020

TABLE 3.—*Mean values of atmospheric pressures, temperatures, vapor pressures, and densities, based on sounding balloon observations at Fort Omaha, Nebr.; Indianapolis, Ind.; Huron, S. Dak.; and Avalon, Cal.*—Continued.

Winter.

Altitude above M. S. L.	Pressures.		Temperatures.		Vapor pressures.		Densities.	
m.	mm.	mb.	°C.	°A.	mm.	mb.	%	kg./cu.m.
0	764	1019	6.0	279.0	3.40	4.53	98.2	1.270
500	720	960	2.1	275.1	2.96	3.95	93.9	1.214
1000	677	903	− 1.5	271.5	2.48	3.30	89.4	1.157
2000	597	796	− 3.3	269.7	1.82	2.43	79.4	1.027
3000	526	701	− 7.8	265.2	1.01	1.35	71.2	0.920
4000	462	616	−12.9	260.1	0.57	0.76	63.8	.825
5000	404	539	−19.4	253.6	.26	.35	57.2	.740
6000	352	469	−26.1	246.9	0.14	0.19	51.2	0.662
7000	306	408	−33.0	240.0	.05	.07	45.8	.592
8000	265	353	−39.0	234.0	.028	.037	40.7	.526
9000	229	305	−45.1	227.9	.015	.020	36.1	.467
10000	197	263	−48.6	224.4	.009	.012	31.5	.408
11000	170	227	−50.6	222.4	0.007	0.009	27.5	0.355
12000	146	195	−51.9	221.1	.006	.008	23.7	.307
13000	125	167	−52.6	220.4	.005	.007	20.4	.263
14000	107	143	−54.3	218.7	.005	.007	17.6	.227
15000	91	121	−54.8	218.2	.004	.005	15.0	.194
16000	78	104	−55.4	217.6	0.004	0.005	12.9	0.166
17000	67	89	−55.2	217.8	.004	.005	11.0	.143
18000	57	76	−54.6	218.4	.004	.005	9.4	.121
19000	49	65	−55.2	217.8	.004	.005	8.1	.104
20000	42	56	−54.3	218.7	.003	.004	6.9	.089
21000	36	48	−54.0	219.0	0.004	0.005	5.9	0.076
22000	31	41	−46.1	226.9	.003	.004	4.9	.064
23000	26	35	−46.0	227.0	.004	.005	4.1	.053
24000	22	29	−45.9	227.1	.004	.005	3.5	.045

Year.

0	760	1013	19.1	292.1	10.54	14.05	93.0	1.202
500	719	959	16.2	289.2	8.47	11.29	88.9	1.150
1000	677	903	13.3	286.3	6.73	8.97	84.6	1.094
2000	601	801	8.4	281.4	4.41	5.88	76.1	0.984
3000	531	708	2.6	275.6	2.72	3.63	69.0	.892
4000	469	625	− 3.5	269.5	1.64	2.19	62.4	.807
5000	412	549	−10.0	263.0	0.90	1.20	55.9	.723
6000	362	483	−16.5	256.5	0.50	0.67	50.7	0.655
7000	316	421	−22.9	250.1	.28	.37	45.4	.586
8000	275	367	−29.6	243.4	.153	.204	40.6	.524
9000	239	319	−36.2	236.8	.080	.107	36.2	.468
10000	207	276	−41.9	231.1	.040	.053	32.2	.416
11000	179	239	−46.8	226.2	0.019	0.025	28.4	0.367
12000	154	205	−50.4	222.6	.010	.013	24.8	.321
13000	132	176	−52.3	220.7	.007	.009	21.5	.278
14000	113	151	−54.1	218.9	.006	.008	18.5	.240
15000	97	129	−55.6	217.4	.004	.005	16.0	.207
16000	83	111	−56.5	216.5	0.004	0.005	13.8	0.178
17000	71	95	−56.0	217.0	.004	.005	11.8	.151
18000	61	81	−54.7	218.3	.004	.005	10.0	.130
19000	53	71	−53.1	219.9	.006	.008	8.6	.112
20000	46	61	−50.9	222.1	.007	.009	7.4	.096
21000	39	52	−49.3	223.7	0.010	0.013	6.3	0.081
22000	34	45	−46.6	226.4	.014	.019	5.3	.068
23000	29	39	−44.0	229.0	.022	.029	4.4	.057
24000	25	33	−40.3	232.7	.038	.051	3.9	.050
25000	22	29	−40.3	232.7	.023	.031	3.4	.044
26000	19	25	−39.0	234.0	0.020	0.027	2.9	0.038
27000	16	21	−38.2	234.8	.015	.020	2.5	.032
28000	15	20	−38.0	235.0	.026	.035	2.3	.030
29000	14	19	−37.1	235.9	.028	.037	2.1	.028
30000	12	16	−36.8	236.2	.030	.040	1.8	.024
31000	11	15	−34.0	239.0	0.051	0.068	1.7	0.021
32000	10	13	−41.9	231.1	.004	.005	1.6	.020

TABLE 4.—*Mean values of atmospheric pressures, temperatures, vapor pressures, and densities, based on sounding balloon observations at Fort Omaha, Nebr.; Indianapolis, Ind.; Huron, S. Dak.; and Avalon, Cal. (English measures).*

Spring.

Altitude above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	Inches.	°F.	Inches.	%	Lbs./cu./t.
0	29.80	62.4	0.372	93.4	0.0754
1000	28.82	59.2	.330	90.9	.0734
2000	27.84	56.1	.287	88.3	.0713
3000	26.85	52.7	.245	85.8	.0693
4000	25.87	49.5	.211	83.2	.0672
5000	24.92	46.4	.187	80.7	.0651
6000	24.02	43.3	0.166	78.3	0.0632
7000	23.15	40.3	.149	75.9	.0612
8000	22.28	37.4	.133	73.5	.0593
9000	21.46	34.5	.118	71.2	.0575
10000	20.63	31.6	.105	68.9	.0556
11000	19.80	28.8	0.091	66.5	0.0537
12000	19.06	26.1	.079	64.4	.0520
13000	18.35	22.6	.067	62.5	.0504
14000	17.64	19.6	.056	60.4	.0488
15000	16.97	16.5	.045	58.5	.0472
16000	16.34	13.3	0.034	56.7	0.0457
17000	15.71	10.2	.027	54.9	.0443
18000	15.12	6.8	.022	53.2	.0430
19000	14.53	3.6	.019	51.6	.0416
20000	13.94	0.3	.016	49.8	.0402
21000	13.39	− 3.3	0.013	48.2	0.0389
22000	12.83	− 7.1	.010	46.6	.0376
23000	12.28	−11.4	.007	45.0	.0364
24000	11.77	−15.9	.006	43.6	.0352
25000	11.26	−20.7	.005	42.2	.0340
26000	10.79	−26.0	0.004	40.9	0.0330
27000	10.31	−31.5	.003	39.6	.0320
28000	9.84	−37.3	.002	38.3	.0309
29000	9.41	−43.1	.002	37.1	.0300
30000	9.02	−47.9	.002	36.0	.0291
Miles.					
6	8.34	−54.9	0.001	33.9	0.0273
7	6.46	−65.2	.0002	26.9	.0217
8	5.12	−67.2	.0002	21.4	.0173
9	4.02	−67.4	.0002	16.8	.0136
10	3.15	−69.5	.0002	13.3	.0107
11	2.44				
12	1.89				
13	1.49				
14	1.14				
15	0.87				

Summer.

0	29.96	76.8	0.588	91.1	0.0735
1000	28.98	75.0	.509	88.5	.0714
2000	27.99	73.2	.441	85.8	.0692
3000	27.01	71.2	.384	83.1	.0671
4000	26.06	68.7	.326	80.7	.0651
5000	25.16	66.2	.281	78.3	.0632
6000	24.25	63.3	0.246	75.9	0.0613
7000	23.43	60.4	.215	73.8	.0596
8000	22.60	57.2	.189	71.6	.0578
9000	21.77	53.8	.163	69.5	.0561
10000	20.94	50.0	.139	67.4	.0544
11000	20.20	46.4	0.119	65.5	0.0528
12000	19.49	42.8	.103	63.6	.0514
13000	18.78	39.4	.089	61.7	.0498
14000	18.07	35.8	.076	59.8	.0483
15000	17.40	32.4	.065	58.0	.0468
16000	16.77	28.9	0.056	56.3	0.0455
17000	16.14	25.7	.047	54.6	.0441
18000	15.55	22.3	.040	53.0	.0428
19000	14.96	18.9	.033	51.3	.0414
20000	14.37	15.4	.028	49.7	.0401

TABLE 4.—*Mean values of atmospheric pressures, temperatures, vapor pressures, and densities, based on sounding balloon observations at Fort Omaha, Nebr.; Indianapolis, Ind.; Huron, S. Dak.; and Avalon, Cal. (English measures)*—Continued.

Summer—Continued.

Altitude above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	*° F.*	*Inches.*	*%*	*Lbs./cu. ft.*
21000	13.82	12.0	0.024	48.1	0.0388
22000	13.31	8.6	.020	46.7	.0377
23000	12.80	5.4	.017	45.2	.0365
24000	12.28	1.9	.014	43.7	.0353
25000	11.77	− 1.5	.012	42.2	.0341
26000	11.33	− 4.9	0.010	40.9	0.0330
27000	10.87	− 8.3	.009	39.6	.0320
28000	10.43	−11.7	.007	38.3	.0309
29000	10.00	−15.2	.006	37.0	.0298
30000	9.57	−18.6	.005	35.7	.0288
Miles.					
6	8.90	−24.7	0.010	33.6	0.0271
7	7.08	−44.5	.004	28.0	.0226
8	5.59	−57.5	.001	22.8	.0184
9	4.37	−66.6	.0002	18.3	.0148
10	3.39	−72.4	.0001	14.4	.0116
11	2.64	−68.8	0.0002	11.1	0.0090
12	2.05	−62.7	.0002	8.5	.0069
13	1.61	−56.9	.0004	6.6	.0053
14	1.26	−52.4	.0006	5.1	.0041
15	1.02	−43.1	.0009	4.0	.0033
16	0.81	−37.5	0.0010	3.2	0.0025
17	0.65	−35.9	.0009	2.5	.0020
18	0.54	−31.9	.0016	2.1	.0017
19	0.46	−29.6	.0020	1.8	.0014
20	0.39	−43.4	.0016	1.5	.0012

Fall.

0	29.87	74.8	0.433	91.3	0.0737
1000	28.91	70.0	.382	89.2	.0720
2000	27.96	65.1	.337	87.1	.0703
3000	27.02	60.1	.298	85.0	.0686
4000	26.10	57.0	.265	82.7	.0668
5000	25.20	54.5	.237	80.2	.0648
6000	24.32	52.0	0.212	77.8	0.0628
7000	23.44	48.7	.185	75.5	.0610
8000	22.58	45.1	.158	73.3	.0592
9000	21.73	41.7	.135	71.1	.0574
10000	20.90	38.1	.115	68.9	.0556
11000	20.11	34.5	0.097	66.7	0.0539
12000	19.36	30.6	.081	64.8	.0523
13000	18.60	27.0	.068	62.7	.0506
14000	17.89	23.2	.058	60.8	.0491
15000	17.23	19.4	.049	59.0	.0476
16000	16.58	15.4	0.041	57.3	0.0462
17000	15.96	11.5	.035	55.6	.0449
18000	15.35	7.7	.030	53.9	.0435
19000	14.74	3.7	.025	52.2	.0422
20000	14.17	0.1	.020	50.6	.0408
21000	13.61	−3.8	0.017	49.0	0.0396
22000	13.05	−7.4	.014	47.4	.0383
23000	12.51	−11.2	.012	45.8	.0370
24000	11.97	−14.8	.010	44.2	.0357
25000	11.50	−18.4	.008	42.8	.0346
26000	11.00	−22.0	0.007	41.3	0.0333
27000	10.55	−25.8	.006	40.0	.0323
28000	10.08	−29.6	.004	38.5	.0311
29000	9.65	−33.0	.004	37.2	.0300
30000	9.25	−36.6	.003	35.9	.0290
Miles.					
6	8.58	−42.9	0.002	33.8	0.0273
7	6.73	−60.0	.0006	27.7	.0223
8	5.28	−64.7	.0003	22.0	.0177
9	4.09	−67.0	.0003	17.1	.0138
10	3.15	−68.1	.0002	13.2	.0107
11	2.48	−65.2	0.0002	10.3	0.0083
12	1.93	−57.5	.0003	7.9	.0064
13	1.54	−49.0	.0007	6.2	.0050
14	1.22	−41.3	0013	4.8	.0039
15	0.96	−40.9	.0029	3.8	.0030
16	0.79	−39.8	0.0001	3.1	0.0025
17	0.63	−39.8	.0001	2.5	.0020
18	0.47	−41.1	.0001	1.8	.0015

TABLE 4.—*Mean values of atmospheric pressures, temperatures, vapor pressures, and densities, based on sounding balloon observations at Fort Omaha, Nebr.; Indianapolis, Ind.; Huron, S. Dak.; and Avalon, Cal. (English measures)*—Continued.

Winter.

Altitude above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	*° F.*	*Inches.*	*%*	*Lbs./cu. ft.*
0	30.09	42.8	0.134	98.2	0.0793
1000	29.03	38.8	.124	95.4	.0770
2000	27.96	34.5	.113	92.8	.0750
3000	26.96	30.6	.102	90.2	.0728
4000	25.96	28.6	.091	87.3	.0704
5000	24.96	27.5	.080	84.1	.0679
6000	24.02	26.6	0.071	81.1	0.0655
7000	23.13	25.2	.062	78.3	.0632
8000	22.25	22.6	.054	75.8	.0612
9000	21.36	20.1	.046	73.1	.0590
10000	20.56	17.2	.039	70.8	.0572
11000	19.76	14.4	0.033	68.5	0.0553
12000	18.98	11.7	.028	66.1	.0534
13000	18.27	8.6	.023	64.1	.0517
14000	17.56	5.4	.019	62.0	.0501
15000	16.88	2.3	.015	60.0	.0484
16000	16.20	−1.5	0.012	58.1	0.0469
17000	15.55	−4.9	.009	56.2	.0454
18000	14.95	−8.7	.008	54.6	.0440
19000	14.32	−12.5	.006	52.6	.0425
20000	13.70	−16.2	.005	50.8	.0410
21000	13.13	−20.2	0.004	49.1	0.0396
22000	12.58	−23.8	.003	47.4	.0383
23000	12.03	−27.4	.002	45.7	.0369
24000	11.50	−30.8	.002	44.1	.0356
25000	11.02	−34.2	.002	42.6	.0344
26000	10.55	−37.7	0.001	41.1	0.0332
27000	10.08	−41.1	.001	39.6	.0320
28000	9.65	−44.3	.001	38.2	.0308
29000	9.21	−47.2	.001	36.7	.0296
30000	8.82	−50.1	.001	35.4	.0286
Miles.					
6	8.18	−54.0	0.0004	33.2	0.0268
7	6.38	−59.6	.0003	26.2	.0212
8	5.03	−63.0	.0002	20.8	.0168
9	3.93	−66.1	.0002	16.4	.0132
10	3.03	−67.7	.0002	12.7	.0102
11	2.36	−66.6	0.0002	9.9	0.0080
12	1.81	−66.1	.0002	7.6	.0061
13	1.42	−65.2	.0002	5.9	.0048
14	1.10	−51.1	.0002	4.4	.0035
15	0.87	−50.4	.0002	3.4	.0028

Year.

0	29.92	66.4	0.415	93.0	0.0750
1000	28.99	62.8	.365	90.7	.0732
2000	27.96	59.2	.317	88.2	.0712
3000	26.97	55.6	.276	85.7	.0692
4000	25.98	53.1	.242	83.0	.0670
5000	25.08	50.7	.213	80.5	.0650
6000	24.18	48.7	0.188	77.9	0.0629
7000	23.31	45.5	.164	75.6	.0610
8000	22.46	42.3	.141	73.4	.0592
9000	21.63	39.0	.121	71.1	.0574
10000	20.80	35.8	.104	68.9	.0556
11000	19.99	32.4	0.089	66.7	0.0538
12000	19.24	29.3	.076	64.6	.0521
13000	18.50	25.9	.065	62.5	.0505
14000	17.80	22.3	.055	60.6	.0489
15000	17.13	19.0	.046	58.7	.0474
16000	16.49	15.8	0.039	57.0	0.0460
17000	15.84	12.2	.032	55.1	.0445
18000	15.24	8.6	.027	53.4	.0431
19000	14.63	5.0	.022	51.7	.0417
20000	14.02	1.4	.019	49.9	.0403
21000	13.46	−2.2	0.016	48.3	0.0390
22000	12.91	−6.0	.013	46.8	.0378
23000	12.36	−9.8	.011	45.2	.0364
24000	11.87	−13.4	.009	43.7	.0353
25000	11.39	−17.0	.008	42.3	.0341

TABLE 4.—*Mean values of atmospheric pressures, temperatures, vapor pressures, and densities, based on sounding balloon observations at Fort Omaha, Nebr.; Indianapolis, Ind.; Huron, S. Dak.; and Avalon, Cal. (English measures)*—Continued.

Year.

Altitude above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	*°F.*	*Inches.*	*%*	*Lbs./cu. ft.*
26000	10.92	−20.6	0.007	40.9	0.0330
27000	10.46	−24.2	.006	39.5	.0319
28000	10.01	−27.6	.005	38.1	.0307
29000	9.59	−31.0	.004	36.8	.0297
30000	9.20	−34.2	.003	35.5	.0287
Miles.					
6	8.54	−39.6	0.002	33.4	0.0270
7	6.77	−54.2	.001	27.4	.0222
8	5.31	−61.8	.0003	21.9	.0177
9	4.13	−67.0	.0002	17.3	.0140
10	3.20	−69.7	.0002	13.5	.0109
11	2.52	−67.2	0.0002	10.6	0.0085
12	1.98	−62.3	.0002	8.0	.0065
13	1.57	−56.4	.0003	6.4	.0052
14	1.22	−50.1	.0007	4.9	.0040
15	0.95	−41.6	.0014	3.7	.0030
16	0.75	−38.6	0.0008	3.0	0.0025
17	0.63	−36.4	.0007	2.5	.0020
18	0.55	−35.1	.0010	2.1	.0017
19	0.47	−36.8	.0017	1.8	.0015
20	0.40	−44.0	.0002	1.6	.0013

TABLE 5.—*Mean annual atmospheric pressures, temperatures, and densities at various heights above sealevel in England.*

Altitude above M. S. L.	Pressure.	Temperature.	Density.
m.	*mb.*	*°A.*	*kg./cu.m.*
0	1014	282	1.253
1000	900	278	1.128
2000	795	273	1.014
3000	699	268	0.909
4000	615	262	0.818
5000	568	255	0.735
6000	469	248	0.658
7000	407	241	0.589

TABLE 6.—*Mean annual densities, as observed at Mount Weather, Va., in the central and western United States and in England.*

Altitude above M. S. L.	Mount Weather, Va.	Central and western United States.	England.
m.	*kg./cu.m.*	*kg./cu.m.*	*kg./cu.m.*
0	1.226	1.202	1.253
1000	1.113	1.094	1.128
2000	1.002	0.984	1.014
3000	0.903	0.892	0.909
4000	0.816	0.807	0.818
5000	0.731	0.723	0.735
6000	*0.672	0.655	0.658
7000	.....	0.586	0.589

* Based on few observations; figures not regarded as reliable.

THE TURNING OF WINDS WITH ALTITUDE.

By WILLIS RAY GREGG, Meteorologist in Charge.

[Dated: Division of Aerological Investigations, Weather Bureau, Feb. 16, 1918.]

Free-air wind conditions, as observed at Mount Weather, Va., have been summarized in the Bulletin of the Mount Weather Observatory (v. 6, pt. 4) and somewhat more briefly in "Meteorology and Aeronautics" by Maj. Wm. R. Blair, recently published by the National Advisory Committee for Aeronautics as Report No. 13. The purpose of the present paper is to present some additional conclusions which may be considered as supplementary to those given in the summaries mentioned; and which are believed to be of considerable interest and value to aviators.

In this summary no free-air observations at altitudes less than 1,500 meters have been used. Those from 1,500 to 2,000 meters have been considered as having reached a height of 2,000 meters. A large number of captive balloon records also have been ignored, as they were made when both surface and upper winds were variable, owing to "flat map" conditions (i. e., no well-developed HIGH or LOW), and no regular or consistent turning of the winds was apparent. Finally, on days when more than one observation was made, only one has been considered, except when the records were obtained under radically different conditions (e. g., before and after the passage of a LOW). With these exceptions, all free-air observations ever made at Mount Weather have been considered, including those in the diurnal series work and in the "International" records in 1913–14. These exceptions should be borne in mind in connection with Table 1, which gives the percentage frequency of winds at the surface from 16 directions.

TABLE 1.—*Percentage frequency of surface winds from 16 directions.*

Direction.	Frequency.
	Per cent.
N	1.0
NNE	0.3
NE	0.4
ENE	0.6
E	0.8
ESE	2.8
SE	12.6
SSE	7.8
S.	7.8
SSW	3.3
SW	2.9
WSW	3.3
W	7.9
WNW	21.6
NW	24.1
NNW	2.5

The values in this table are slightly different from those in Table 22, v. 6, part 4, Bulletin of the Mount Weather Observatory (repeated in Table 2, p. 44, of Report No. 13, Meteorology and Aeronautics). The latter table is, however, based on observations during 1911–12 only and includes those in which an altitude of less than 1,500 meters was reached. Of the observations in the summer months to a height of less than 1,500 meters, a large proportion were made with a surface wind from north-northeast to east. This wind was in nearly all cases very shallow, and above it there was a layer about 1 kilometer in depth with little, if any, wind. At higher levels clouds, if present, usually indicated a westerly wind. Those observations in winter to less than 1,500 meters in height were usually made in a surface westerly wind which rapidly increased in velocity with altitude, thus beating the kites down. It is probable that these winds would show about the same turning tendencies as those indicated later for the westerly winds.

TABLE 2.—*Mean turning of winds with altitude, when surface winds are of moderate velocity.*

Direction at earth's surface.	Number of observations.	Percentage turning—		
		Clockwise.	Counterclockwise.	Not turning.
		%	%	%
N. to ENE.	31	45	35	20
E. to ESE.	50	76	12	12
SE. to SW.	474	94	2	4
WSW	46	76	7	17
W	109	51	12	37
WNW	298	41	29	30
NW	337	29	40	31
NNW	34	35	38	27

The following remarks are based on yearly averages. The same tendencies are shown in all the months, but more decidedly in the winter than in the summer half of the year. With surface winds of moderate velocity the turning with altitude for the year is given in Table 2. A detailed study showed that certain groups of surface winds have practically the same turning characteristics—viz, north, north-northeast, northeast, and east-northeast; east and east-southeast; and southeast, south-southeast, south, south-southwest, and southwest. In the first group the tendency to clockwise turning is somewhat greater than that to counterclockwise, about 20 per cent showing no turning. In the second group the clockwise turning is large, about 75 per cent. In the third group it amounts to about 94 per cent. It is greatest, 98 per cent, with south-southeast and least, 89 per cent, with southwest winds. Surface winds from west-southwest, west, west-northwest, northwest and north-northwest could not be grouped and are therefore given individually. The clockwise tendency decreases with surface winds from west-southwest to northwest, being 76 per cent for west-southwest, 51 per cent for west, 41 per cent for west-northwest, and 29 per cent for northwest, the counterclockwise turning being, respectively, 7, 12, 29, and 40 per cent. Winds aloft were the same as at the surface in 17, 37, 30, and 31 per cent of the cases, respectively. Surface north-northwest winds show about an equal tendency to clockwise and counterclockwise turning.

TABLE 3.—*Percentage frequency of a west component at different levels up to 4,000 meters.*

Sea-level altitude.	Number of observations.	West component.
m.		%
* 526	1,378	66
1,000	1,378	79
2,000	1,378	88
3,000	854	94
4,000	397	96

* Surface of ground at Mount Weather, Va.

In Table 3 is shown the percentage frequency of a west component in the winds at various levels. It amounts to 66 per cent of all the observations made at the surface and increases to 96 per cent at 4,000 meters, being higher at all levels in the winter than in the summer months. Little difference is apparent in the value of this component at 3,000 and 4,000 meters. This is also shown by the observations with sounding balloons at Fort Omaha, Nebr., Huron, S. Dak., and Indianapolis, Ind. These observations are not sufficiently numerous or well distributed throughout the year to give definite values, but are of interest in that they show the same general tendencies.

TABLE 4.—*Percentage frequency of north and south components at 3,000 and 4,000 meters under different conditions of wind direction at the surface.*

Direction at earth's surface.	Number of observations.	North component.	South component.	Due west.
At 3,000 meters:		*Per cent.*	*Per cent.*	*Per cent.*
E. to WSW	323	9	66	25
W	82	39	11	50
WNW. to ENE	449	76	6	18
All directions	854	47	29	24
At 4,000 meters:				
E. to WSW	152	11	54	35
W	46	39	13	48
WNW. to ENE	199	73	8	19
All directions	397	45	26	29

Table 4 gives the percentage frequencies of north and south components at 3,000 and 4,000 meters under different conditions of wind direction at the surface. These figures indicate that a southerly component in the surface winds still persists in 66 per cent of all cases at 3,000 meters and in 54 per cent at 4,000 meters; it shifts to northerly in 9 per cent and 11 per cent, respectively. In the other 25 and 35 per cent, respectively, the wind aloft is due west. With surface westerly winds a northerly component prevails in 39 per cent of the cases at 3,000 and 4,000 meters, and a southerly component in about 12 per cent, the remaining 49 per cent continuing west. With surface winds having a northerly component, this component persists in about three-fourths of the cases at 3,000 and 4,000 meters, being 76 and 73 per cent, respectively. At those altitudes there was a southerly component in 6 and 8 per cent of the cases; west winds prevailed in the remaining 18 and 19 per cent. When all observations are considered, it is found that, at 3,000 and 4,000 meters, respectively, due west winds prevail 24 and 29 per cent of the time; a northerly component 47 and 45 per cent, and a southerly component 29 and 26 per cent.

The foregoing discussion and tables are based on average conditions and it is necessary, in predicting wind conditions aloft, to know the pressure distribution prevailing at the time, as charted on daily weather maps. When this distribution is known, fairly reliable forecasts of wind directions can be made by the following rules:

RULES FOR FORECASTING WINDS ALOFT.

(1) With a distant LOW approaching from the southwest, surface winds are easterly and shallow, and above them is a layer about 1 kilometer in depth in which there is little or no wind; above this layer southwesterly winds prevail.

(2) As a LOW passes north of the station, surface winds are successively southeast, south, and southwest, and the turning of wind with altitude is clockwise, the upper winds nearly always being southwest to west.

(3) With a LOW northeast of the station and a HIGH southwest, both surface and upper winds are northwest. As this HIGH approaches and passes south of the station the surface winds are successively west-northwest, west and west-southwest, turning clockwise with altitude to northwest.

(4) With a HIGH east of the station and a LOW approaching from the west or west-northwest, winds are southwest and strong both at the surface and aloft.

(5) With a HIGH north of the station and a LOW approaching from the southwest and passing south of the station, surface winds are north-northeast to east-northeast and there is little turning up to 4,000 meters; the turning at higher levels is counterclockwise to north-northwest and northwest.

(6) With a HIGH northwest and a LOW south of the station, surface winds are north to northeast, turning clockwise with altitude to northeast, and at higher levels counterclockwise back to north-northwest.

(7) With a HIGH on the northwest and a LOW passing northward east of the station, surface winds are successively north, north-northwest, and northwest, turning counterclockwise with altitude to northwest and west-northwest.

(8) In general, the turning of winds with altitude is usually such that they have a westerly component before the 3-km. level is reached.

HALO OF JANUARY 10, 1918, AT BOULDER, COLO.

In Science for February 15, 1918, pages 170–171, O. C. Lester reports the observation, at Boulder, Colo., of brilliant halo phenomena on January 10.

The phenomena included the 22°-halo, with a portion of its parhelic circle and its 22°-parhelia. The halo was bright, showed red inside and faint blue outside, and was accompanied by the upper fragment of the circumscribing halo ("ox-yoke curve").

The 46°-halo developed also, complete to the horizon (colors red inside and blue outside), with a strongly colored upper tangent arc.

With increasing altitude the parhelic circle became almost complete, developed the paranthelia of 120°; and the parhelia of 22° became dazzling, considerably elongated vertically, and colored orange red on the sides away from the sun.

At 11 a. m. the 22°-halo appeared as a complete circle with the inferior summit showing brightly; the 46°-halo and its upper tangent reached almost to the zenith.

Measurements were made with an improvised transit. The air was quiet and filled with falling ice crystals [needles?]. Temperature, −3° to −4° (F.?).

DIFFRACTION OF LIGHT IN THE FORMATION OF HALOES.[1]

By S. W. VISSER.

[*Reprinted from* Science Abstracts, Sect. A, Oct. 31, 1917, § 238.]

Haloes are commonly considered to be formed by the refraction of the sun's rays through ice crystals, and this explanation was adopted by J. M. Pernter among others. This theory does not account for all the features of haloes in an entirely satisfactory manner. In the present paper the author suggests a modification of the usual theory by taking into account the effects of diffraction.

The ordinary theory is discussed in detail. It is found that it leads to a maximum intensity of illumination in the case of the 22°-halo at an angle of 22½° from the sun, whereas observation shows this angle to be actually a little less than 22°. It is also difficult to explain by means of the simple refraction theory, the great variety of colors which are sometimes seen. When diffraction is taken into account, the size of the ice crystals becomes a matter of importance. In the calculations here made these are assumed to be homogeneous in size, a condition specially favorable to the development of color. An application of the diffraction theory to a special case gives very satisfactory agreement between the theoretical distribution of the colors and that actually observed. The side of the hexagonal ice crystal is calculated, in this case, to be 0.279 mm. It is found that very small crystals will lead to a halo which has a red inner edge and in which no other color is seen but white, while larger crystals produce more distinct coloring. It is urged that accurate observations of the coloring of halos should be made, as without this information reports are of little or no value.—*J. S. Di*[*nes*].

[1] Proc., K. Akad, Amsterdam, 1917, 19: 1174–1196.

HORIZONTAL OSCILLATION OF THE FREE ATMOSPHERE UP TO 10 KM., AT BATAVIA.[1]

By W. VAN BEMMELEN and J. BOEREMA.

[*Reprinted from* Science Abstracts, Sect. A, Nov. 30, 1917, § 1235.]

The data used for the determination of the diurnal variation of wind velocity at different heights is taken from pilot-balloon ascents made both by day and by night during the seven months May to November at Batavia when the prevailing winds are easterly. A variation comprising 24-hour and 12-hour terms has been assumed and the values of the harmonic constants were determined by the method of least squares, from the difference in velocity found between pairs of consecutive ascents. By this means it is hoped that nonperiodic variations have been largely eliminated. The east-west and north-south components have been dealt with separately. The general coast line runs east-west at Batavia and, as would be expected, the influence of land- and sea-breezes is distinctly felt in the north-south component at the lower levels. The mixing of upper and lower wind currents by convection (Espy-Köppen effect) also makes its influence felt. It is found that these influences may be neglected above 4 km. and the present discussion is mainly confined to the levels above this height, while the lower layers will be dealt with separately in a later paper.

A series of observations is at present in progress from a small island in the Java Sea where the conditions approximate more closely to those over the open ocean. The results from the present series for levels above 4 km. show (1) that the amplitude of the 24-hour variation is small for both north and east components; (2) that the 12-hour term of the north-south component is also small, though more definite than the 24-hour term; and (3) that the amplitude for the 12-hour term of the east-west component is much larger and increases from about 28 cm./sec. at the surface to 54 cm./sec. at 4 km. It then decreases to 22 cm./sec. at 7 km. and increases again to 38 cm./sec. at 10 km. The phase angle diminishes up to 4 km. and above this remains almost constant at 150° to 6 km. The observations are not at present numerous enough to allow of any very accurate determination of the changes of phase above this height. In the lower layers the variations seem to be in agreement with the theoretical results which Gold has deduced from the pressure variations.—*J. S. Di*[*nes*].

[1] Proc., K. Akad. Amsterdam, 1917, 20: 119–135.

EARLY USE OF KITES IN MILITARY OPERATIONS.

In an interesting paper, "Chinese Contributions to Meteorology," Mr. Co-Ching Chu states [2] that the use of kites for military purposes was devised in China even before the time of Archytas of Tarentum [about 400–350 B. C.],[3] who built a wooden dove. Moti (500–400 B. C.) mentions a genius Kung-Shu Pan who spent three years building a bird of wood and bamboo, which, when finished, flew in the air for three days and three nights without apparent tendency to fall and was used to attack the capital of Sung in the interest of the then hostile State of Tsou.—C. A., jr.

[2] Geographical Review, New York, Feb,, 1918, 5: 136–137.

[3] The dates for Archytas of Tarentum are from Johnson's New Universal Cyclopedia, New York, 1884.—C. A., jr.

SECTION II.—GENERAL METEOROLOGY.

AIR CHIMNEYS OF ICE BELOW A WATERFALL.

By ROBERT E. HORTON, M. Am. Soc. C. E.

[Dated: Albany, N. Y., Feb. 5, 1918.]

On the morning of December 12, 1917, the writer observed an unusual formation of ice below a waterfall created by a dam on the Oswegatchie River, near Gouverneur in northern New York. The air temperature on the morning when the observations were made was about −25°F. There had been freezing weather at this location for sometime preceding. The dam is of timber [fig. 1 not accurate in this] and is located at the crest of a natural rapid in a rough but shallow granite gorge. There was a slight depth of water wasting over the spillway of the dam in places. This depth ranged from zero to perhaps 6 inches. Owing to projecting rocks and piles of pulp wood below the dam (*C* in fig. 1) the flow of water away from the toe of the dam was greatly obstructed and there was opportunity for shore ice to build out from some of these obstructions, starting at a distance of about 20 feet below the dam and reaching out over the pool to within, say 10 feet, of the toe of the dam. In several places there were vertical chimneys of ice of circular cross section built up on this shore ice. (*A*, *B*, in fig. 1.) Where, owing to a higher crest, water did not flow over the dam, shore ice had also built out from the toe of the dam and here again the ice chimneys were formed. The tallest of these chimneys was about 4 feet high and 6 or 7 inches inside diameter, the walls apparently being ½ inch to 1 inch in thickness. The largest ice chimney was 10 or 12 inches in diameter, but this one was not over 2 feet high.

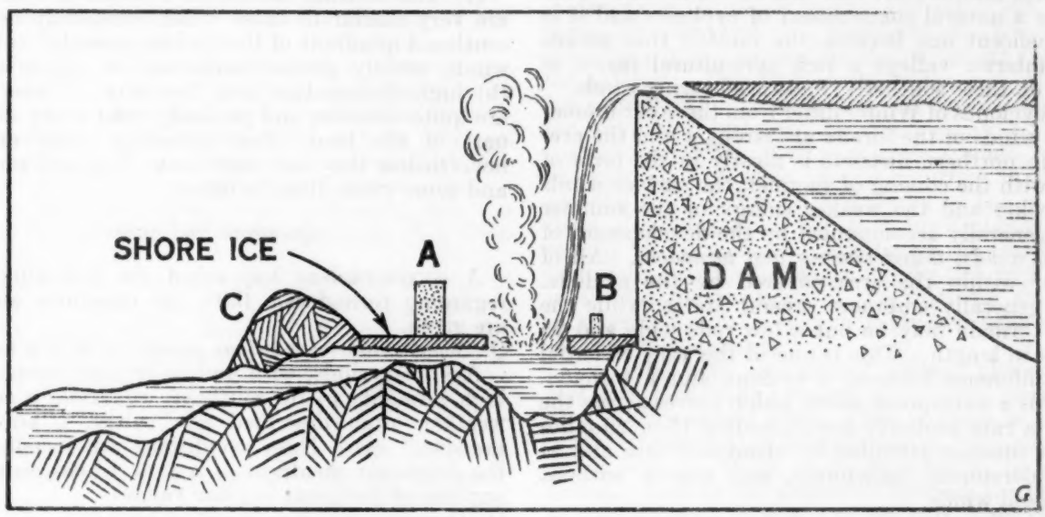


FIG. 1.—Illustrating formation of air-built ice chimneys, *A* and *B*, on shore ice below a dam on the Oswegatchie, near Gouverneur, N. Y., December 12, 1917. Obstructions of rock and pulp wood at *C*. Dam should be of timber.

Apparently the overflow from the dam carried air down with it into the pool. The turbulent water rising under the shore ice permitted the escape of this air, first through air holes. Mist and drops of water expelled with this escaping air froze around the margin of the air hole, gradually building up an ice chimney. In the case of the shorter chimneys, mist and particles of water could still be seen escaping.

Although the writer has been around northern streams much of the time for 20 years, this is the first occasion when he has observed this phenomenon, although it would seem natural from the simple conditions under which it is produced that it must be of rather common occurrence.

CYCLONES, TORNADOES, THUNDERSTORMS, SQUALLS.

By ALFRED J. HENRY, Meteorologist.

[In response to a query from an honored correspondent the Weather Bureau recently submitted the following elementary remarks on cyclones and on tornadoes, with the purpose of clearing away once more the usual misconceptions regarding the distinctions meteorologists make between these storms. As all our stations repeatedly encounter the kinds of questions here brought up and answered, the remarks are published *in their entirety* that all may use them when needed.—EDITOR.]

What is a tornado? Students of weather phenomena define a tornado as a violent windstorm accompanied by rain, hail, thunder, and lightning, in which the air masses whirl with great velocity about a central core while the whole storm travels across the country in a narrow path at a considerable speed. These storms have a destructive diameter of from a few hundred feet to half a mile and sometimes more. When seen from a distance the tornado has the appearance of a dense cloud mass with one or more pendant funnel-shaped clouds which may or may not reach to the earth. In the larger tornado clouds east of the Mississippi the funnel cloud may not be noticeable unless the observer be situated in a favorable position for observing it, but the whirling motion of the air is the same whether the funnel is visible or not.

(1) Tornadoes almost invariably occur in the southeast quadrant of a cyclone, that is the barometric con-

figuration marked LOW on the daily weather map. The cyclone or area of low pressure or simply LOW of the daily weather map, indicates certain atmospheric conditions essential for the generation of tornadoes. However, many cyclones occur without tornadoes, but a tornado does not occur without a cyclone.

(2) On the average about 120 "cyclones" pass across the United States in the course of a year, moving in a general way from the west to the east. The characteristics of a cyclone are: Cloud and rain. The temperature of the air constituting the front or advancing air masses is warmer than that of the air masses in the rear. The surface wind circulation in a cyclone is spirally inward toward the region of lowest pressure, counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. A complete statement of the wind circulation in "cyclones" would far exceed the limits of this paper but it may be found in any standard treatise on meteorology.

(3) It will suffice for our purpose to say that cyclones, after crossing the Rocky Mountains and entering the Plains States in their eastward movement, induce a movement of the surface air from the south and southeast. When this circulation persists for a day or so, the following result is commonly experienced, viz, an increase in the temperature and moisture of the air. This condition is a natural concomitant of cyclones and it is a very beneficent one because the rainfall that makes the great interior valleys a rich agricultural region is dependent on these southerly, moisture-bearing winds.

(4) The cyclones of Winter differ from those of Summer in that the winds of the former are stronger and the precipitation in northern districts is mostly in the form of snow, but with the coming of summer, the surface winds become weaker and the weaker energy of the summer cyclone is generally accompanied by the development of *violent local winds, thunderstorms, and tornadoes.* All of these occur within the area covered by the cyclone. That area generally embraces several States, while the track of a tornado may be but a few rods wide and 25 to 50 miles in length. This is one of the very essential points of difference between a cyclone and a tornado. The former is a widespread storm which moves across the country at a rate probably not exceeding 15 or 20 miles an hour, in summer attended by cloud and rain and at times thunderstorms, hailstorms, and mostly without violent general winds.

(5) Practically all cyclones of the warm season are attended at some time and at some place by one or another of the following-named phenomena: (*a*) a simple, harmless thunderstorm, with more or less brilliant electrical display; (*b*) a part of the precipitation of the thunderstorm may occur in the form of hail, and then we have a hailstorm; (*c*) violent winds may occur, blowing in a straight line. These winds may be of sufficient violence to unroof houses and destroy frail structures; many of the storms of this class are *improperly called* tornadoes.

(6) Finally, *the real tornado* is to be distinguished by several unmistakable characteristics, first, the whirling columnar of air and pendant funnel-shaped cloud, whose lower end is always in physical contact with the earth when it causes destruction. Whether or not the funnel cloud can be seen depends somewhat upon the size of the storm, on the viewpoint of the observer and also the time of day. In the dry regions of the Great Plains the funnel cloud is often plainly visible miles away across the prairies, but in the more humid districts east of the Mississippi River, where the cloud mass is much greater, it is sometimes impossible to perceive the funnel cloud in the darkness and rain produced by the general rain cloud. The second characteristic is a very significant roar that has been likened to the rumbling of distant thunder or the approach of a train of heavy cars; and finally, after the storm has passed, the lay of the débris will generally indicate whether there has been a twisting or whirling motion of the winds. If the débris lies parallel with the course of the storm, then the winds have been straight-line rather than spiral or curving and the storm was not a tornado.

Tornadoes almost invariably travel in an easterly direction. The *prevailing* direction is from the southwest to the northeast. The width of the path of great destruction varies from a few rods to half a mile; in extreme cases a width of as much as a mile has been reported. The average length of the path of great destruction is about 25 miles, although here again individual cases vary greatly from the average. Great destruction is not always continuous throughout the entire path of the storm, but occurs only where the funnel cloud is in contact with the earth. The funnel cloud sometimes rises and passes over considerable distances before again descending to earth.

(7) The weather conditions associated with tornadoes are very similar to those which commonly occur in the southeast quadrant of the cyclone, namely: (a) southerly winds, mostly gentle; sometimes no appreciable wind; (b) high temperature and humidity. These conditions are quite common and probably exist every day in some part of the land. But tornadoes occur only rarely, nevertheless they are much more frequent some seasons and some years than in others.

Questions and answers.

A correspondent has asked the following questions regarding tornadoes. Both the questions and answers are given.

Q. What weather conditions prevail prior to a tornado?

Ans. A cyclone, with unusually high temperature and high humidity in its southeast quadrant, a condition of weather often described as "sultry," "sticky," "oppressive," etc. These conditions are usually found in the southeast quadrant of a LOW whose center overlies any one of the great interior valleys.

Q. Does rain follow or precede a tornado?

Ans. It may precede, accompany, or follow, and on rare occasions it may be absent.

Q. How long before a tornado sets in will a barometer record its coming?

Ans. The barometer does not indicate the coming of a tornado, although, as above stated, tornadoes occur with the greatest frequency in an area of low barometer at certain seasons.

Q. Can a barometer be depended on?

Ans. Not to indicate the approach of a tornado; but a recording barometer, if within the influence of a tornado, may give a valuable and interesting record.

Q. During what months of the year can tornadoes be looked for in the Mississippi Valley?

Ans. Tornadoes may occur in the Gulf States in winter. As the season advances the region of greatest frequency is found in the Plains States and the Mississippi Valley, May being the month of occurrence of the greatest number, April coming next. East of the Appalachians tornadoes occur rarely until after July. The

season of tornadoes in the Mississippi Valley extends from April to September, inclusive.

Q. In case a cyclone cellar is not available, what, in your estimation, would be a safe place?

Ans. The southwest portion of the cellar of a frame house.

Q. What about cellars in brick buildings during such storms; are they safe?

Ans. That depends entirely on the severity of the tornado. Some tornadoes merely destroy the roof of brick houses; some cause the walls to crumble or fall outward. The cellar of a brick house is probably safer than any other place in that particular structure. In the Omaha tornado of March, 1913, very few brick houses were seriously damaged.

Q. What time of day do these storms occur?

Ans. Generally from 3:30 to 5 p. m.

Q. Have there been any at night?

Ans. Yes.

Q. Have the municipalities any way of notifying the people, and how?

Ans. The place where a tornado will form can not be foretold. Tornadoes, like thunderstorms and hailstorms, occur, for the most part, on warm, sultry afternoons, in the late spring and in summer. While the precise path of these storms can not be accurately foretold, the weather maps show when the conditions are favorable to their generation.

The local signs of the approach of a tornado are ominous clouds, first in the southwest and then almost immediately in the northwest and north. The appearance of a pendant funnel-shaped cloud may be taken as conclusive evidence of the presence of a tornado. If a funnel cloud can not be observed, its existence can be known by a peculiar roaring noise, somewhat like the rumbling of distant thunder or the approach of a train of heavy cars.

If one can see the tornado cloud and gain an idea of its direction of motion, then the zone of safety is in a line at right angles to the direction of motion. If the tornado is moving toward the northeast, then one should run toward the northwest, provided, of course, the storm is about to move a little to the south of the observer's position.

The southern margin of a tornado is more dangerous than the northern, and one should take advantage of this fact in the endeavor to reach a place of safety, remembering that usually the width of the path of great destruction does not cover more than a couple of city blocks and that comparative safety may be found only a short distance at right angles to the line of advance of the tornado.

DETERMINATION OF OZONE AND NITROGEN OXIDES IN SOUTHERN INDIA.[2]

By F. L. USHER and B. S. RAO.

[*Reprinted from* Science Abstracts, Sect. A, Oct. 31, 1917, §1094.]

The more rapid decay of rubber articles and textile fabrics in the Tropics generally is ascribed to the intense light and heat, and the supposed higher percentage of ozone, hydrogen peroxide, and nitrogen oxides in the tropical atmosphere. As there are hardly any reliable data concerning these percentages, the authors undertook this determination at Bangalore College in southern India (Mysore). Rothmund and Burgstaller have shown that the potassium iodide method of estimating ozone and hydrogen peroxide is untrustworthy, they rely on the oxidation by ozone of alkaline or neutral sodium nitrite to nitrate, and they let the air to be analyzed replace water, instead of bubbling it through water. The air is sucked through tubes charged with chromic acid (which destroys H_2O_2) and MnO_2 (neither of these two reagents attack nitrogen peroxide).

Only 14 complete determinations have been made so far, and in 12 of these none of the three gases were found; twice nitrogen peroxide was observed, 1 part in 4,000,000 or 5,000,000 of air. Conclusions are not yet drawn, but it is pointed out that apparently ozone and nitrogen peroxide never occur together in the atmosphere, probably because they would react with one another under formation of nitric acid.—*H. B[orns]*.

[2] Trans., Chem. soc. j., Aug., 1917, 111: 799–809.

PITFALLS OF METEOROLOGICAL PERIODICITIES.

By W. W. B[RYANT].

[*Reprinted from* Nature, London, Nov. 29, 1917, 100: 246–7.]

There is a real danger that some meteorologists, resenting the accusation frequently made against them of accumulating masses of data without making any real use of them, may be tempted to apply the processes of mathematical analysis to any and every set of observations, regardless of the considerations which limit the suitability of the method for the particular data proposed for analysis. This may easily be the case when hunting for periodicity. There is a great temptation, especially for anyone accustomed to the regularity of so many cosmic phenomena, such as eclipses, comets, planets, etc., to expect to find such periods recurring in the weather, but the work before us, consisting of the essential portions of a dissertation by Dr. Ryd—fortunately thought worthy by Capt. Ryder, director of the Danish Meteorological Institute, of a wider publication and so included in the Communications of the Institute and done into intelligible English—should be studied before much time is spent in the search.[1]

Dr. Ryd sets out clearly certain characteristics of meteorological data, wherein they differ essentially from e. g., astronomical data. One of these is the impossibility of eliminating some forms of "systematic" error, which are too likely to be variable to be strictly systematic, such as the difference between the indications of a thermometer, under various conditions of exposure, and the real temperature of the air. Another is an error neither accidental nor systematic, but due to the fact that the data are meteorological; a good example of this is afforded by the mean diurnal variation of air temperature as shown on (*a*) overcast or (*b*) cloudless days.

Dr. Ryd regards harmonic analysis applied to such data as an excellent interpreter, but a very untrustworthy probe. The known periods—the day and the year—are unexceptionable, and the variation from hour to hour in one case, and from day to day, or preferably from "pentad" to "pentad," in the other, are obviously fit subjects for analysis. Dr. Ryd prefers to use both sine and cosine terms instead of the usual transformation, because the determination of mean error is more direct when two constants enter similarly. This is clearly important, as the mean error is a vital consideration. Analysis for testing a real period, such as one of the lunar periods, on the meteorological data is not quite so risky as tentative fishing for an unknown period, in

[1] Publikationer fra Det Danske Meteorologiske Institut Meddelelser. No. 3, "On Computation of Meteorological Observations, by *V. H. Ryd* (Copenhagen, 1917).

which case at least one coefficient, according to Dr. Ryd, must be five times its probable error before it can be regarded as likely to be real.

The brochure is divided into two sections, the first dealing generally with such routine problems as the computation of the mean error, smoothing and adjustment of observational data, and harmonic analysis, with an additional chapter on secondary minima and maxima in the annual variation of the temperature, in which the author deals with the proverbial "Ice-men" of May 11, 12, and 13, and exposes the weakness of Dove's supposed proof of the reality of this legendary phenomenon. The second part deals fully with "mechanical" adjustment, factors of variation, and suggestions on the choice of adjusting formulæ, of which several are given, and a longer chapter is devoted to the working out of four concrete examples, viz, the hourly inequality of air temperature, Greenwich, 1849 to 1868; and of pressure, Greenwich, 1854 to 1873; the annual inequality of pressure, Batavia, 1876 to 1905; and the annual variation of temperature, Copenhagen, 1875 to 1910, the last being a case of partial data—only three observations at fixed hours of the day, instead of the full set.

Dr. Ryd reminds the reader that when data such as July air temperature for 20 years are entered in rows for days and in columns for years, they can not be analyzed similarly in both directions, inasmuch as the successive days are not independent, while the columns are. He also discusses at some length the "order" to which harmonic analysis, if used for adjustment, should be pushed, with hints for saving labor; but on the whole he prefers the "mechanical" adjustment with a suitable formula in the majority of cases, and thinks this method less liable to introduce new errors into a problem.

RELATION BETWEEN BAROMETRIC PRESSURE AND THE WATER LEVEL IN A WELL AT KEW OBSERVATORY.

By E. G. BILHAM.

[Presented to the Royal Society, London, Nov. 15, 1917.]

(*Reprinted from* Nature, London, Nov. 22, 1917, 100: 239.)

The water level shows a well-marked response to changes of barometric pressure at all times of the year. Under similar conditions a given increase of pressure, δp, will depress the water level in the well by an amount δu, which is proportional to δp. The value of $\delta u/\delta p$ varies with the mean level of the water, but is always negative. The validity of the equation $\delta u = a.\delta p$ was established between limits given by $dp/dt > 0.5$ mb./hr., and the value of a was determined in the case of three groups of months representing high, intermediate, and low levels. The sensitiveness of the water level to pressure was found to increase rapidly with the height of the water, the value of a for a height of 360 cm. above mean sealevel being four times as great as for a height of 200 cm. The change of sensitiveness appears to be entirely due to the change in the condition of the soil. The average value of a is 1.1 mm./mb. There appears to be no lag in the response of the well to changes of pressure, and under favorable conditions the most rapid fluctuations of pressure are shown on the water level trace.

In the original of this paper Mr. Bilham has worked out in mathematical detail careful observations similar to the more general ones discussed by the undersigned in the REVIEW for February, 1916, p. 75–76.—C. A., jr.

PHENOMENA CONNECTED WITH TURBULENCE IN THE LOWER ATMOSPHERE.

By G. I. TAYLOR.

[Presented to the Royal Society, London, Nov. 15, 1917.]

(*Reprinted from* Nature, London, Nov. 22, 1917, 100: 239.)

In a previous paper by the author it was shown theoretically that a connection should exist between the rate at which heat is conveyed into the atmosphere by means of eddies, and the amount of retardation of the velocity of the lower layers of the atmosphere behind the gradient velocity due to the friction of the ground. In the present paper the amount of the turbulence over Paris is calculated from temperature observations taken on the Eiffel Tower. It is shown that the amount is the same as that calculated from observations of the change in direction of the wind between the bottom and top of the Eiffel Tower due to the friction of the ground. The daily variation in wind velocity which depends on the daily variation in turbulence is next discussed, and it is shown that the chief characteristics of the observed phenomena of daily variation are explained, both qualitatively and, so far as is possible, quantitatively by the author's equations.

SWISS SOCIETY OF GEOPHYSICS, METEOROLOGY, AND ASTRONOMY.[1]

Under M. Mercanton of Lausanne, as chairman, a circle of the more active Swiss physicists, meteorologists, and astronomers assembled in the great physics lecture room of the University of Berne on April 28, 1917, to organize the society of the above name (Société Suisse de Géophysique, Météorologie et Astronomie) and adopt statutes in conformity with its proposed activities as a section of the Helvetian Society of Natural Sciences (Société helvétique des Sciences naturelles). The following officers were elected for 1917–1919: President, Prof. Dr. P.-L. Mercanton, of Lausanne; vice-president, Prof. Dr. A. de Quervain, of Zurich; secretary-treasurer, Prof. A. Kreis of Coire.

The first regular general meeting of the society was held September, 11, 1917, at Zurich, with an attendance of 34, out of 70 members already enrolled. The assemblage was welcomed, in the name of the Helvetian Society of Natural Sciences, by Dr. J. Maurer, Director of the Federal Meteorological Bureau, who congratulated the young society on the lively interest already awakened for it, and then retired in favor of the president, M. Mercanton.

After some discussion, the society unanimously adopted the proposal by P. Ditisheim (La Chaux-de-Fonds), a noted Swiss horologist, that the Federal Council be requested to adopt the serial numeration of the hours of the day, 1 to 24. This is a conscious renewal of the majority recommendation of the International Prime Meridian and Time Congress of Washington (1884), but would be only a rather tardy step for the Swiss Government. The system has been in use on the Indian railways since 1859, was legalized for Canada in 1891,[2] was actually introduced into Italy in 1893 with the adoption of Central European Time, was approved in 1895 at the London (fifth) session of the International Railway Congress, was adopted in Belgium in 1897, and put into practice by the Bureau des Longitudes (Paris) in all its publications in 1900; has been used by the French railways since July 1,

[1] Compte rendu des séances de la Société Suisse de Géophysique, Météorologie, et Astronomie (G. M. A.) *in* Archives des sci. phys. et nat., 122ème année, 4 ème pér., Genève, 15 nov. 1917, 44: 345, fol.

[2] The system has been in actual use on the C. P. railway west of Winnipeg for many years.

1912, and in all her Postes et Télegraphes publications. In 1913 the Swiss railways requested authority to employ this numeration, and the Swiss Federal Meteorological Commission is actually employing it.

An American plea for the 24 hours' numeration was published in this REVIEW May, 1909 (**37**: 175), by C. A. Mixer, who stated that he had been using it for many years in the records of his business, as well as in his weather records, and finds it a much simpler system than the customary one.

About 15 papers were presented at this first meeting of the society, and the abstracts of those subjects most interesting to our readers will be found translated in the REVIEW for December, 1917.—C. A., jr.

Lawrence Hargrave, 1850–1915.[1]

By R. GREIG-SMITH, D. Sc.

(From his presidential address, Royal Society of N. S. Wales, May 3, 1916.)

Mr. Lawrence Hargrave was a well-known figure at our meetings, which he attended regularly even to the June meeting preceding his death on July 6, 1915, at the age of 65 years. The son of the late Mr. Justice Hargrave, he was born in England, but came to Australia in 1866 at the age of 16. Being of a mechanical turn of mind, he entered an engineering firm in Sydney, where he received the training that subsequently enabled him to construct the models and build the engines, etc., which his inventive genius designed. It was as an engineer and explorer that he first developed, and he took no small share in the early exploration of British New Guinea. He formed one of a party of adventurers who equipped the *Maria* for an exploring expedition. On her way north this unseaworthy old craft was wrecked in February, 1872, on the coast of North Queensland. A considerable number of her company were killed by the aborigines, but Hargrave was fortunate in escaping with his life and returned to Sydney. Joining a scientific expedition organized by Sir William Macleay, he sailed from Sydney in the *Chevert* in May, 1875. But too short a visit was made to New Guinea to satisfy Hargrave, who accordingly left the *Chevert* at Cape York in September. With Petterd and Broadbent he then joined O. C. Stone in an excursion inland from Port Moresby. Their discoveries in this direction are recorded by Stone in "A few Months in New Guinea." In May, 1876, Hargrave joined D'Albertis, as engineer of the *Neva*, in which they ascended the Fly River farther than any European had previously penetrated into the interior of Papua. The hardship and exposure of this journey induced severe attacks of fever, and in September, 1876, he concluded his travels and came back to Sydney.

He worked for some years as an assistant astronomical observer at the Sydney Observatory under the late Mr. H. C. Russell, but gave this up and devoted many years to the study of aeronautics, and the success of the present-day aeroplanes is largely [?] dependent upon Hargrave's invention of the box kite. He first studied the motions involved in the flight of birds, and prepared models embodying the principles of the various movements. The success of the models convinced him of the possibility of mechanical flight, and although he did not prepare a complete machine, he was so satisfied with the result of his work that he gave his ideas on the subject to this society in August, 1884. The models which served to illustrate his papers are now in the Technological Museum, Sydney. The continuance of his investigations led him to the invention of the cellular or box kite, which he described in 1895.[2]

It is as the inventor of this kite that his name is so well known, for it has been used by practically every military nation in the world for signaling purposes and by scientists for meteorological investigations.[3] It does not follow that our aeroplanes would not have been invented but for the box kite, only it is certain that his invention hastened the evolution of the aeroplane in no small degree. It is upon his invention that other men have built and become famous.

Latterly he devoted some attention to the meaning and significance of certain rock carvings and markings on the rocks around Port Jackson and the Hawkesbuyr River.

Mr. Hargrave was of a quiet and retiring disposition, and preferred to discuss the various subjects in which he was interested, and in which he had a deep knowledge, to a small circle of friends rather than to a large audience. His familiar face will be sadly missed by those members of our society who rarely saw his favorite seat vacant at the meetings.

Frank Plummer, 1868—1918.

By G. N. SALISBURY, Section Director.

[Weather Bureau office, Seattle, Wash., Jan. 29, 1918.]

We regret to record the death of Mr. Frank Plummer, cooperative observer, at his home in Port Townsend, Wash., on January 21, 1918. Mr. Plummer established the Weather Bureau station at Port Townsend on June 17, 1897, and maintained its record unbroken for a period of 20 years and 7 months.

He was born in Port Townsend, August 17, 1868, and was the son of A. A. Plummer, one of the first white settlers there about 1850. Frank Plummer had been prominent in various ways in the life and progress of his native town, and it is gratifying to learn that his careful and valuable meteorological record, a testimonial to his unwavering public spirit, is to be maintained by his widow, Mrs. Mae M. Plummer.

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[1] *See* Jour. and proc., Roy. soc. N. S. Wales, Sydney, 1916, 50: 3–5.

[2] *See also* Flying machine motors and cellular kites, by *L. Hargrave*. Jour. & proc., Royal soc. New South Wales, Sydney, June 7, 1893, 27: 75–81, Plates I–IV.—C. A., jr.

[3] *See* MONTHLY WEATHER REVIEW, April, 1896, 24: 114, and July, 1897, 25: 312; also note on p. 22.—C. A., jr.

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS, JANUARY, 1918.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated: Weather Bureau, Washington, D. C., Feb. 1, 1918.]

GENERAL PRESSURE DISTRIBUTION OVER NORTH AMERICA AND THE ADJACENT OCEANS.

Reports from Midway Island and Honolulu were missing from January 7 to 26 inclusive. Over the northeastern Pacific Ocean and Alaska there was a regular series of low and high pressure areas, each three in number, none especially marked except the first low and the following high area, the latter extending in marked form into Alberta. The high area during the closing days of the month was also quite marked, with an extension into Alberta.

Over the United States pressure was generally low, abnormally so during two periods which are discussed in some detail below; and it was not until the closing days of the month that there was a decided rise in pressure, which, however, did not maintain its pronounced character over the eastern portion of the country, except over Newfoundland. There abnormally low pressure prevailed during the greater portion of the month, indicating the persistence of a strong area of high pressure to the north and northeast. No reports are received from this latter section, but it is believed that the erratic movement and general behavior of several of the western disturbances after they reached the eastern portion of the country may safely be attributed to such an extensive and sluggish high area as that above mentioned, as low pressure also ruled over the northern and middle North Atlantic Ocean as indicated by the reports received from Bermuda.

STORMS AND WARNINGS.

The first 23 days of the month of January, 1918, were remarkable for the persistence of a type of pressure distribution that resulted in the most severe period of winter weather over that portion of the United States lying east of the Rocky Mountains that has ever been recorded within the 47 years of the history of the Weather Bureau.[1] Snow and ice storms, notable because of their frequency, intensity, and wide extent covered the entire area from Canada to Mexico, the Gulf and Florida, and low temperatures were equally widespread, the line of zero temperature extending into northern Texas and that of freezing temperature to the southern limits of the Florida mainland. While the temperatures were not as low, as a rule, as on some previous occasions and the records for the month of January were equaled or exceeded over very large areas, yet the outstanding feature was the persistence of the cold weather, and in this respect the record over a large portion of the East and South stands without a parallel. For instance, at Washington, D. C., during the first 24 days of January the average daily deficiency in temperature was 10.5 degrees, while for the 30 days from December 26, 1917, to January 24, 1918, both dates inclusive, it was 11.6 degrees, a hitherto unprecedented occurrence.

[1] Appropriate divisions of the Central Office have been charged with the preparation of a detailed discussion of the meteorological conditions characteristic of this almost unprecedented winter, together with the conditions leading up to it, and a comparison with other severe winters of this continent.—C. A., jr.

The low temperatures were also associated with unusually frequent snowfalls, that often proved heavy, especially in the region of the Great Lakes and the great Central Valleys, and in two instances the southern limit of snow extended to the western coast of the Gulf of Mexico.

The persistence of any type of weather depends, of course, on the equal persistence of a reasonably uniform type of pressure distribution. The pressure type may vary considerably as to details of intensity and direction and rapidity of movement, yet the general type presents certain characteristics that are—in the main—uniform when once definitely developed. During this month of January, 1918, the type was that of low-pressure areas from the extreme Southwest moving in a general northeasterly direction, with high-pressure areas of great magnitude to the northwest that were naturally accompanied by low temperatures.

The localities of origin of these southwestern low-pressure areas were not often the same, yet, once they had reached the extreme Southwest and had begun their northeastward movement, their behavior was quite uniform and in keeping with the well-known tendencies of this class of storms. Whether they continued in a true northeasterly direction or whether they were deflected to the northward or eastward, depended almost entirely on the changing pressure over the western Atlantic Ocean, and the character of this change was not always apparent when the storms began their northeastward march.

As a whole, the history of one of these storms is the history of all, and intimate discussion of each can be justified only by a desire to preserve a record of minute details. This work has been accomplished so frequently in the past that it seems hardly necessary to again attempt it, and therefore only one of the greatest storms will be treated in extenso.

This storm appeared off the extreme southern coast of California on the morning of January 8, 1918. During the ensuing 36 hours it moved slowly, but with greatly increased intensity, to southwestern Colorado (at Durango its central pressure was 29.44 inches), with a strong and cold high-pressure area to the northward (central at Edmonton, Alberta, pressure = 30.84 inches, −22° F. on the evening of Jan. 9). It then turned southeastward and on the evening of the 10th was central over extreme southern Texas (Corpus Christi, pressure = 29.42 inches), the high-pressure area closely following with snow, strong northerly winds and a cold wave (Amarillo, Tex., −2° F.). Here the storm turned northeastward by way of the extreme lower Mississippi Valley and on the morning of the 11th it was central over southeastern Louisiana (New Orleans, 29.32 inches), with heavy snow to the northward and snow and ice storms in eastern Texas. At 10:30 p. m. of the 10th southeast storm warnings were ordered on the Gulf coast from Bay St. Louis to Cedar Keys, Fla.; and southwest warnings on the following morning over the remainder of the eastern Gulf coast and along the Atlantic coast from Miami, Fla., to Georgetown, S. C., while the remaining Gulf warnings were changed to northwest. Advisory warnings for strong north winds and snow were also sent to open ports on Lake Michigan.

On the evening of the 10th cold-wave warnings had also been ordered for Tennessee, Alabama, Mississippi,

western Georgia, and extreme northwestern Florida, and extended on the morning of the 11th to central and northern Florida, eastern Georgia, the Carolinas, the Ohio Valley, lower Michigan, and the western upper Lake Region. Warnings of heavy snow were also ordered for the lower Lake Region, the upper Ohio Valley, the Middle Atlantic States, and southern New England. By the evening of January 11 the storm center was over extreme eastern Tennessee (28.98 inches at Knoxville), the general disturbance extending from southern Florida to Lake Superior, with heavy snows to the northward and northwestward and heavy rains in the east Gulf States and western Georgia. The cold wave had reached extreme northwestern Florida and severe gales had occurred where storm warnings had been displayed, as well as over the interior district. At 10.30 p. m. southeast storm warnings were extended along the Atlantic coast to Boston, and cold-wave warnings ordered for the Middle Atlantic States. On the morning of the 12th the storm was central over Georgian Bay, with a barometer reading of 28.70 inches at Saugeen, Ontario, and all conditions—snow, gales, and cold—had occurred over the interior districts and in the South Atlantic States, the cold wave reaching New England by the morning of the 13th.

During this storm the wind reached a velocity of 60 miles an hour from the northwest at Pensacola, Fla., 56 miles an hour from the south at Jacksonville, Fla., 72 miles an hour from the southwest at New York City, and 80 miles an hour from the southwest at Buffalo, N. Y. The line of 0° F. extended into northern Alabama on the morning of the 12th and the line of 18° to the Middle Gulf coast, while on the following morning the line of freezing temperature extended southward as far as Fort Lauderdale, Fla. Temperature records for the month of January were lowered over many of the central and southern districts east of the Rocky Mountains, and heavy snow fell from northeastern Texas northeastward through the Lakes Region and northern New England. Gales continued along the New England coast until the night of the 13th, and warnings were continued accordingly.

The next storm was also a very severe one, and it was first observed on the morning of the 12th over extreme northern British Columbia, appearing as an offshoot from a general depression over the Aleutian Islands. This was also the time of greatest development of the preceding storm over Georgian Bay. The second disturbance moved rapidly down the western slope of the Rocky Mountains, and by the morning of the 14th was central over northwestern Louisiana (Shreveport, 29.52 inches). It then turned northeastward with somewhat increased velocity of progression and passed into the Gulf of St. Lawrence on the morning of the 16th, having reached its maximum intensity on the previous evening over extreme eastern Maine (Eastport, 28.72 inches).

A recital of the storm's history would merely be a repetition of that of the previous one except as to specific details, and only the rapid approach of the third storm, which was over eastern Texas on the evening of January 15, prevented another cold wave in the South. Other less violent storms followed in rapid succession, although the type sequence was temporarily interrupted from the 22d to the 26th by a northwestern disturbance that moved eastward over the northern portion of the country.

In addition to those mentioned above, storm warnings were ordered on the following dates: 14th, 15th, 18th, 19th, 21st, 22d, 26th, 27th, and 28th. The major portion were verified, either wholly or in part, while several failed on account of erratic movement and decreasing intensity.

Cold-wave and frost warnings were ordered also on the following dates: 15th, 18th, 19th, 20th, 22d, 23d, 25th, 26th, 27th, 28th, and 31st. Quite a number of these failed of verification on account of the persistence of high pressure over the middle and southern North Atlantic, which could not be anticipated.

Heavy-snow warnings were issued for the Middle Atlantic States and southern New England on the 22d, the only ones except those of the 11th previously mentioned.

A warning of strong northwest to north winds for the Panama Canal zone was issued on the 11th, and a maximum wind velocity of 27 miles an hour from the northwest was recorded on the 14th. The Chief Hydrographer of the Panama Canal reported that "it is probable that the winds may have reached gale force at no great distance seaward."

Special bulletins regarding cold weather and snow were issued on the 10th, 12th, 14th, 24th, and 30th, and were prepared with special reference to their effect upon railroad activities and the distribution of food and fuel.

WARNINGS FROM OTHER DISTRICTS.

Chicago, Ill., forecast district.—A storm of marked intensity moved northeastward from Texas to the southern Lakes Region during January 5–6, and at the same time an area of high pressure and low temperature developed over Manitoba and moved southward. Accordingly cold-wave warnings were ordered for the upper Mississippi and middle Missouri valleys. These warnings were only partially verified on account of the rapid eastward advance of a disturbance from the far Northwest.

Warnings were issued well in advance of the severe cold wave which overspread Montana on the 9th and moved rapidly southeastward, reaching Illinois during the night of the 10th-11th. Warnings of strong northerly winds and snow were also issued for the benefit of the cattle interests in Wyoming and the Plains States.

No further warnings were issued until the evening of the 18th, when cold-wave warnings were ordered for eastern Wyoming and cattle warnings for southwestern Nebraska and western and central Kansas. The former were fully verified, but the weather conditions in the Western Plains States were not severe on account of the filling up of a disturbance which moved southeastward into Texas.

On the evening of the 24th the pressure-change chart showed a marked fall in pressure over the northern Plateau and northern Pacific States, with a marked rise over northern Manitoba and Saskatchewan. Such conditions are usually quite favorable for the development of an area of high pressure and low temperature over the Northwest, accordingly cold-wave warnings were issued for the northern border States and as far south as Iowa, Nebraska, and Wyoming. The following morning warnings were ordered for Kansas and western and central Missouri, and on the evening of the 25th and morning of the 26th for eastern Missouri and Illinois. The warnings were fully verified in practically all sections.

The next cold-wave warnings of importance were ordered for western Montana on the evening of the 28th and for Wyoming, Kansas, western Iowa, and western and central Missouri on the 29th. These warnings were fully verified.

Heavy-snow warnings were issued for northern and central Illinois and southeastern Wisconsin on the evening of the 27th.—*Chas. L. Mitchell, Assistant Forecaster.*

New Orleans, La., forecast district.—Periods of cold weather, mostly following barometric depressions that developed in the southern ends of troughs of low pressure moving eastward from the Rocky Mountain Region, were unusually frequent during January, 1918; and marked activity was shown by the cyclonic disturbances.

On indications of the 8 p. m. chart of January 4, southeast storm warnings were issued for the Louisiana coast and the east coast of Texas; but the disturbance moved farther inland as it gained intensity and the warnings were lowered the next morning.

Intense weather conditions prevailed over the western half of the country on the 10th, and midday special observations showed that a depression over the Southwest had been forced southward over Texas by a large area of high pressure. The following warning was issued:

Hoist northwest storm warning 2 p. m., Morgan City, La., to Brownsville, Tex. Disturbance over southern Texas, with high pressure to northward, will cause moderate to fresh northerly gales to-night and Friday. Rain turning to snow and much colder Thursday night and Friday.

At 3 p. m. southeast warnings were ordered for the Louisiana coast east of Morgan City and changed to northwest the next morning. The warnings from Velasco, on the east coast of Texas, to Morgan City, La., were continued at 2 p. m. of the 11th, with orders to lower at sunset. The warnings were verified. The maximum velocities exceeded 40 miles an hour along the Texas coast and reached 56 miles at Galveston.

Because of a marked disturbance over New Mexico, shown on the 8 p. m. map of the 13th, southeast storm warnings were ordered for the Texas coast and extended the following morning over the Louisiana coast. The disturbance moved eastward across the Gulf States, attended by strong winds to moderate gales, as forecast.

A disturbance over Texas, on the morning of the 19th, gave some promise of development. Small-craft warnings were issued for the Louisiana and Texas coasts and were changed to northwest storm warnings for the east coast of Texas at 2 p. m. Small-craft warnings were again displayed on the Texas coast on the 20th, being changed from storm warnings on the east coast. These warnings were verified, the highest velocities occurring during the night of the 19th–20th on the east coast of Texas.

A large area of high pressure was moving southward on the 26th, as shown by the 8 p. m. map, and northeast storm warnings were ordered for the Texas coast. A moderate gale occurred on the west coast and fresh winds on the east coast.

On the morning of the 2d, colder weather was predicted for the interior of the district, with freezing in Oklahoma and Arkansas, near freezing in northern Louisiana, and frost nearly to the coast in Louisiana and Texas. No marked area of high pressure appeared on the map, but a depression central over Kentucky was moving in an unusual southeastward course. A marked change to colder followed, reaching the proportions of a cold wave in eastern and central Oklahoma and northwestern Arkansas.

On indications obtained in special observations, on the 5th, cold-wave warnings were issued for central and northeastern Oklahoma and northwestern and central Arkansas. At night the warnings were extended over the northern portion of east Texas and the remainder of Arkansas, and on the morning of the 6th were ordered for the southern portion of east Texas. The warnings were timely and were verified except on the west coast of Texas, where the temperature fall was slightly less than was expected.

Cold-wave warnings issued for Arkansas on the 9th proved to be premature, although a change to colder occurred. In the early afternoon warning of a cold wave with snow and strong northerly winds was issued for the Texas Panhandle and northwestern Oklahoma, and was verified. The warning was extended eastward and southward, at night and the following morning, to include all of Oklahoma, northwestern Arkansas, and the northern portion of Texas. The approach of severely cold weather was now apparent and special observations were called for. Early in the afternoon of the 10th, cold-wave warnings were ordered for the remainder of the forecast district, with forecasts of northerly gales, snow in the interior, rain turning to snow on the coast, and temperatures below freezing to the coast by the following morning. The cold wave reached the Texas coast on the morning of the 11th, bringing a fall of 30 to 40 degrees to a temperature of 22° at Corpus Christi and Galveston. Snow and winds occurred as forecast. Although temperatures were already much below freezing in Arkansas on the morning of the 11th, warning of a cold wave was repeated for eastern and southern Arkansas as well as for Louisiana, with zero temperatures in Arkansas, zero to 10° in northern Louisiana, and 10° to 16° in the sugar and trucking region of southern Louisiana. Temperatures slightly below zero were recorded in Arkansas, and temperatures in Louisiana occurred as forecast. At New Orleans the temperature on the 11th fell from 67° at 7 a. m. to 24° at 7 p. m., and reached a minimum of 17° in the early morning of the 12th. Previous low-temperature records in Arkansas were broken. Plumbing was extensively damaged in southern Louisiana, and many young citrus fruit trees were killed. The forecasts contained a special warning to protect live stock and vegetation and to drain water pipes. Losses, though considerable, were diminished by precautions taken.

On January 14, a well-defined area of low pressure was over extreme eastern Texas. The high-pressure area over the central Plains States was small and only relatively high, while a considerable depression overspread the far Northwestern States. Midday special observations were called for and cold-wave warnings were ordered for the southern portion of eastern Texas, and for Palestine in northeastern Texas. The cold wave occurred in the area named and also at Muskogee, Okla., Fort Smith, Ark., and Shreveport, La. At Muskogee and Fort Smith, continued cloudy and cold weather during daytime of the 14th was followed by an ordinary temperature fall at night.

A cold wave occurred in the central and southeastern portions of the district on the 20th–21st, for which warnings were issued on the morning of the 19th. For western Texas, no warnings were issued in this instance and no cold wave occurred except in the southwestern portion, where (El Paso) the temperature was high at 7 p. m. of the 19th and fell decidedly in the following 24 hours, as an area of low pressure in that vicinity was displaced by the western edge of an area of high pressure.

On the 26th–27th and 30th–31st, respectively, extensive areas of high pressure moved southward over the district, causing cold waves over the interior, for which timely warnings had been issued. Due to unsettled conditions over the Gulf, the temperature along the Gulf coast was not as low as was expected in either instance.

Forecasts of frost, or temperatures of freezing or lower, to or nearly to the coast, were made on two-thirds of the days of the month and were nearly all verified. Special attention was given to conditions affecting live stock and the shipment of perishable commodities. The scarcity of fuel enchanced the importance of the forecasts.

Fire-weather warnings were issued for the forested regions of Oklahoma and Arkansas on the 5th and for Oklahoma on the 9th, and conditions occurred as forecast except that snow continued to fall in western Arkansas somewhat longer than predicted. The fire hazard was lessened during the greater part of the month by the snow covering.—*R. A. Dyke, Assistant Forecaster.*

Denver, Colo., forecast district.—While January, 1918, in the Denver Forecast District was colder and stormier than common, severe conditions were confined principally to the region east of the Continental Divide. The storm activity on the eastern slope resulted, for the most part, from the abnormal paths taken by several northwestern low-pressure areas, which instead of moving eastward were deflected southward, following closely the Continental Divide to southwestern Texas. In the wake of each of these LOWS there followed strong anticyclonic conditions from the Canadian Northwest and severe cold spread over the Plains Region to the lower Rio Grande Valley and adjacent parts of Mexico and the Gulf districts.

In addition to these depressions having their origin in the distant north a low-pressure area, followed by the lowest temperatures of the month, developed in the southern Plateau States during the night of January 8. Its front reached the Plains Region in advance of the northern anticyclone whose front thereafter moved rapidly southward along the east side of the Continental Divide. Cold-wave warnings were issued the evening of the 9th for eastern Colorado and eastern New Mexico. The warnings were fully verified. At Roswell, N. Mex., the 24-hour temperature-fall on the 10th was 51 degrees.

At 1 p. m. of the 25th cold-wave and live-stock warnings were issued for northeastern and middle eastern Colorado; at night these warnings were extended to include southeastern Colorado, and on the morning of the 26th to include eastern New Mexico. During the afternoon of the 25th the low center overlay north-central Colorado with an elongation of the depression northwestward to British Columbia and southeastward to central Texas. At this time the crest of the high-pressure area was north of the Dakotas. During the following 12 hours fresh LOW centers formed in Oklahoma, southeastern Colorado and northern Arizona while a general increase of pressure occurred over the northeastern Rocky Mountains slope. Temperatures fell rapidly, justifying the warnings issued. At Denver the 24-hour temperature fall was 56 degrees. In the afternoon of the 28th a low-pressure area was central in northern Idaho and 12 hours later in central Wyoming with loops extending northwestward to Washington and southward to southeastern New Mexico. Anticyclonic conditions overlay Alberta and Assiniboia. Cold-wave warnings and live-stock warnings were issued for eastern Colorado with the morning forecasts and in the afternoon were extended to include eastern New Mexico. On the morning of the 30th temperatures had fallen to zero, or lower, throughout eastern Colorado and 24 hours later to zero in northeastern New Mexico and 16° in southeastern New Mexico.

Rain in southern Arizona on the 13th and again from the 25th to 27th, inclusive, was accurately forecast. On the morning of the 28th killing frost was reported from Yuma; later reports indicated that no damage resulted from the temperature of 30° reported. Notice of freezing temperature in central Arizona on the morning of the 29th was included in the forecast of the 28th.—*Frederick H. Brandenburg, District Forecaster.*

San Francisco, Cal., forecast district.—Like the two preceding months, the storms passing eastward from the north Pacific during January, 1918, entered the continent at a high latitude. As a result of this storm movement the northern portion of the San Francisco forecast district received ample precipitation, which was well distributed throughout the montn while the southern portion was abnormally dry. No excessive daily amounts of precipitation were reported. There were a large number of rainy days in Washington, Oregon, and Idaho, but the precipitation fell in such moderate amounts that it nearly all penetrated the soil and there was only a moderate run-off. The only rains of any consequence in California occurred in the northern portion on the 12th, 13th, and 14th, when the amounts were moderate; and in the southern portion on the 13th and 14th and again on the 25th and 26th, when moderate amounts fell at most stations, with quite heavy rains in the extreme south and at some foothill stations.

Taking the record at San Francisco, which extends over a period of 69 years, as a basis, there has been less rain this season to date than any previous record, and there is practically no snow in the mountains except on the high isolated peaks. At Summit, where the Southern Pacific Railroad crosses the Sierra Nevada Mountains, elevation 7,017 feet, the average depth of snow on the ground at the end of January is a little over 125 inches, but this year there were only 2 inches on the ground. These comparisons illustrate the seriousness of the drought condition in northern California, and in the south it is about the same.

The temperature was above the normal throughout the entire district. In the northern portion both day and night temperatures were high, while in the southern portion the nights were comparatively cool and the days warm. There were but few sudden and marked changes in temperature during the month, the transitions to colder or warmer weather in most cases being gradual. Frosts occurred frequently in California, but they were not of marked severity, and little or no damage resulted, and there were but few nights when it was necessary for the citrus growers to smudge.

Storm warnings were ordered from the Columbia River northward on January 1, 3, 4, 6, 17, and 28; from Port Harford to San Diego on the 9th; from Point Reyes to Eureka on the 25th; and at Point Reyes on the 12th. While the warnings were not verified in all cases, it is believed that they were warranted by the conditions and appreciated by the marine interests.—*G. H. Willson, District Forecaster.*

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS DURING JANUARY, 1918.

By ALFRED J. HENRY, Meteorologist in Charge.

[Dated: River and Flood Division, Weather Bureau, Mar. 1, 1918.]

A sudden break-up of the ice in the rivers of the northern States and the great interior valleys has been viewed with much apprehension. It is a most significant fact that notwithstanding the knowledge as to the thickness of the ice on the rivers and that its breaking up was an absolute certainty, yet when the break came, and it came under favorable rather than unfavorable circumstances, a loss of probably 50 per cent of the total tonnage of the Ohio and Mississippi below Cairo was sustained. The direct money loss involved is upward of $2,000,000 and the indirect loss through revenues, etc., is much greater; this loss is particularly felt at this time, since it is practically impossible to replace in 1918 the craft that have been destroyed.

The break came first on the southern tributaries of the Ohio; namely, the Great Kanawha, Guyandotte, Big Sandy, Licking, and Kentucky Rivers, and with the lapse of only a few days the ice on the Green River of Kentucky and both the Cumberland and the Tennessee Rivers broke up at rather high stages.

The direct cause of the break-up was the rains which set in on January 26 and again on the 28th. The rains of the second period were considerably heavier than those of the first. The second period was attended by thawing weather, although the high temperatures lasted probably less than 48 hours, being followed by cold weather on the 29th and 30th.

The Great Kanawha, Guyandotte, Big Sandy, Licking, and Kentucky were the first rivers to respond to the rains of the 28th. The rainfall was augmented by much snow water, and the great quantity of water contributed by the mountain streams soon caused a rise to flood stage and consequently the breaking up of the ice. The latter gorged in many places, and with the breaking of the gorges a vast quantity of water was released, which, with its burden of heavy ice, simply crushed and carried away floating property of all description.

Much damage was done to river craft that had sought refuge, earlier in the season, in the mouths of the respective streams, under the impression that an anchorage there would be a protection from the ice of the main river. It is estimated by a writer in the Evansville Press of January 31, 1918, that 50 per cent of all Ohio and Mississippi River tonnage has been wiped out and that the vessels lost were representative of the best on the river. The loss was particularly heavy at Paducah, Ky., due to the ice from the Tennessee, in conjunction with heavy ice coming down the Ohio.

As before stated, it is a significant fact that vessel interests, although being fully aware of the danger river craft was subject to, were helpless, with the means at their command, before the tremendous crushing power of the ice floes borne along on the flood wave that swept down the river.

Table of flood losses during January, 1918, not including losses among river craft.

Drainage district.	Tangible property, bridges, buildings, factories, etc.	Farm property.		Suspension of business.	Value of warnings.
		Crops.	Live stock.		
South Atlantic:					
Columbia, S. C.	$0	$0	$638	$140	$31,900
Mississippi:					
Parkersburg, W. Va.	9,600	0	0	0	.....
Tennessee	.....	.....	.....	8,000	.....
East Gulf:					
Alabama rivers	1,000	.....	220	950	5,100
Do	.....	500	.....	600	.....
Total	10,600	500	858	9,690	37,000

At the close of the month the Ohio was badly gorged between Rising Sun and Madison, Ind., also between Evansville and Newburg, Ind. The high stages at Cincinnati were due to backwater from gorges below that city.

The ice in the Mississippi below Cairo was badly gorged at several places, particularly at Osceola, Ark. Below that point much heavy ice passed down the river during the closing days of the month, the southern limit of floating channel ice being between Vicksburg and Natchez, Miss. The channel at the first named place was two-thirds full of floating ice on the 25th.

In a later number of the REVIEW it is hoped to present a detailed report on the ice of the current winter in the Mississippi and its tributaries.

Floods due to rains elsewhere in the south-central regions were infrequent, although flood stages were reached in rivers of North and South Carolina and Alabama as may be seen from the tables below.

There were also destructive floods in the rivers of Washington and Oregon due to heavy rains the last of December, 1917, and the first few days of January, 1918. The damage in Washington was confined to railroad tracks and bridges. Transcontinental lines were tied up several days due to loss of bridges and washouts.

The rivers of New England and the Middle Atlantic States also the northern tributaries of the Ohio were, as a rule, icebound throughout the month.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 1.—*Flood stages in Atlantic drainage during January, 1918.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Roanoke	Weldon, N. C.	30			27.8	31
Fishing Creek	Enfield, N. C.	14			13.7	31
Neuse	Neuse, N. C.	14	31	(†)	15.4	31
	Smithfield, N. C.	13	30	(†)	15.3	31
Cape Fear	Elizabethtown, N. C.	22	31	(†)	23.4	31
Great Pee Dee	Cheraw, S. C.	27	31	(†)	30.0	31
Santee	Rimini, S. C.	12	15	21	13.3	18–19
			30	(†)	13.0	31
	Ferguson, S. C.	12	17	24	13.1	21
Catawba	Catawba, S. C.	11			10.8	30
Wateree	Camden, S. C.	24	31	(†)	27.3	31
Saluda	Chapells, S. C.	14	30	(†)	14.5	31

† Continued into February.

TABLE 2.—*Flood stages in the Mississippi drainage during January, 1918.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Ohio	Portsmouth, Ohio	50			49.5	29
	Cincinnati, Ohio	50	31	(†)	60.0	31
	Dam 37, Fernbank, Ohio.	54	31	(†)	54.4	31
Monongahela	Fairmont, W. Va.	25	29	29	25.0	29
	Greensboro, Pa.	20			18.7	29
Little Kanawha	Glenville, W. Va.	22	29	29	22.7	29
	Creston, W. Va.	20	29	29	22.0	29
Great Kanawha	Charleston, W. Va.	30			27.7	29
Elk	Clay, W. Va.	18			16.4	29
Tug	Williamson, W. Va.	26	29	29	38.3	29
Big Sandy	Lock No. 3, Louisa, Ky.	50			47.0	29
	Pikeville, Ky.	35	28	29	50.0	29
Green	Lock No. 2, Rumsey, Ky.	34			30.6	31
	Lock No. 4, Woodbury, Ky.	33	29	(†)	40.7	31
	Lock No. 6, Brownsville, Ky.	30	31	(†)	30.1	31
Kentucky	Jackson, Ky.	24	28	29	35.0	29
	Beattyville, Ky.	30	29	29	45.0	29
	High Bridge, Ky.	30	31	(†)	31.2	31
	Frankfort, Ky.	31			30.2	29
Cumberland	Williamsburg, Ky.	22	29	(†)	24.8	31
	Burnside, Ky.	50	28	30	69.5	29
	Celina, Tenn.	45	29	(†)	54.5	31
	Carthage, Tenn.	40	29	(†)	51.2	31
	Nashville, Tenn.	40	29	(†)	46.1	31
	Dover, Tenn., Lock B.	49	31	(†)	49.8	31
	Fox Bluff, Tenn., Lock A.	43	30	(†)	43.9	30
	Clarksville, Tenn.	46	30	(†)	48.2	31
Tennessee	Knoxville, Tenn.	12			24.2	29
	Loudon, Tenn.	25			23.5	31
	Chattanooga, Tenn.	33	30	(†)	38.4	31
	Bridgeport, Ala.	24	31	(†)	24.5	31
	Guntersville, Ala.	31			29.4	31
	Florence, Ala.	18			17.5	31
	Riverton, Ala.	32	31	(†)	32.6	31
Clinch	Speers Ferry, Va.	20	29	29	24.5	29
	Clinton, Tenn.	25	29	(†)	37.6	30
	Kingston, Tenn.	25	30	(†)	29.0	31
Powell	Tazewell, Tenn.	20	29	29	27.2	29
Little Tennessee	McGee, Tenn.	20	29	29	20.8	29
Hiwassee	Charleston, Tenn.	22			21.5	31
French Broad	Penrose, N. C.	13	29	29	13.6	29
	Asheville, N. C.	4	28	29	5.0	28
	Dandridge, Tenn.	12	29	29	15.3	29
Big Pigeon	Newport, Tenn.	6	29	29	12.0	29
			31	(†)	6.0	31
Holston	Rogersville, Tenn.	14	29	29	20.0	29
Holston (North Fork).	Mendota, Va.	8	28	29	14.0	29
			31	(†)	8.0	31
Holston	Bluff City, Tenn.	12			10.8	28

† Continued into February, 1918.

TABLE 3.—*Flood stages in the East Gulf and Columbia River drainages during January, 1918.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
East Gulf drainage:		*Feet.*			*Feet.*	
Alabama	Selma, Ala.	35			32.7	15
Tallapoosa	Milstead, Ala.	40			38.6	12
Coosa	Gadsden, Ala.	22			21.0	31
Do	Lock No. 4, Lincoln, Ala.	17	31	(†)	18.8	31
Tombigbee	Demopolis, Ala.	39			35.7	31
Black Warrior	Tuscaloosa, Ala.	46	31	(†)	53.9	31
Columbia River drainage:						
Columbia	Vancouver, Wash.	15	(*)	5	18.3	1
Willamette	Albany, Oreg.	20	14	14	20.0	14
Do	Eugene, Oreg.	10	12	15	14.0	12
Do	Oregon City, Oreg.	10	(*)	2	14.5	21
			13	21	11.0	16
Santiam	Jefferson, Oreg.	10	11	12	12.0	11

† Continued into February, 1918. * Continued from December, 1917.

MEAN LAKE LEVELS DURING JANUARY, 1918.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Feb. 5, 1918.]

The following data are reportd in the Notice to Mariners of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during January, 1918:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.93	580.76	571.91	246.07
Above or below—				
Mean stage of December, 1917	−0.23	−0.04	−0.72	−0.38
Mean stage of January, 1917	−0.82	+0.30	+0.31	+0.81
Average stage for January, last 10 years	−0.08	+0.94	+0.28	+0.72
Highest recorded January stage	−0.85	−1.91	−1.64	−1.53
Lowest recorded January stage	+1.05	+1.68	+0.95	+2.27
Average relation of the January level to—				
December level	−0.3	−0.2	±0.0	±0.0
February level	+0.2	±0.0	±0.0	−0.2

* Lake St. Clair's level: In January, 574.04 feet.

SECTION V.—SEISMOLOGY.

SEISMOLOGICAL ABBREVIATIONS USED IN THE INSTRUMENTAL REPORTS.

CHARACTER OF THE EARTHQUAKE.

I = noticeable.
II = conspicuous.
III = strong.
d = (terræ motus domesticus) = local earthquake (sensible or felt).
v = (terræ motus vicinus) = near-by earthquake (within 1,000 km.).
r = (terræ motus remotus) = distant earthquake (1,000 to 5,000 km. distant).
u = (terræ. motus ultimus) = very distant earthquake (beyond 5,000 km.).
Δ = distance to epicenter.

PHASES.

P = (undæ primæ) = first preliminary tremors.
PRn = P waves reflected n times at the earth's surface.
S = (undæ secundæ) = second preliminary tremors.
SRn = S waves reflected n times at the earth's surface.
PS = transformed waves; longitudinal (P) to transversal (S) or vice versa.
L = (undæ longæ) = long waves in the principal portion.
M = (undæ maximæ) = greatest motion in the principal portion.
C = (coda) = trailers.
O = time at epicenter.
L_{trep1} = long waves reaching the station from the anti-epicenter (40,000 km. $-\Delta$).
L_{trep2} = long waves again reaching the station from the anti-epicenter (40,000 km. $+\Delta$).
F = (finis) = end of perceptible trace.

NATURE OF THE MOTION.

i = (impetus) = abrupt beginning.
e = (emersio) = gradual appearance.
T = period = twice the time of oscillation.
A = amplitude of the earth's movement, reckoned from the zero line.
E, N, or Z attached to a symbol signifies the E–W, the N–S, or the vertical component, respectively, thus:
A_E is the E–W component of A.
A_N is the N–S component of A.
A_Z is the vertical component of A.
} Measured in microns (μ), $\frac{1}{1000}$ mm.

INSTRUMENTAL CONSTANTS.

T = period of instrument.
V = magnification of instrument.
ϵ = damping ratio.

SEISMOLOGICAL REPORTS FOR JANUARY, 1918.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Seismological Investigations, Weather Bureau, Washington, Mar. 2, 1918.]

TABLE 1.—*Noninstrumental earthquake reports, January, 1918.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1918.	*H. m.*		° ′	° ′			*M. s.*			
Jan. 14	.....	Eureka	40 48	124 11	.....	1	.....	.....	.....	U. S. Weather Bureau.
16	12 00	Brawley	33 00	115 31	3	1	.....	None	.....	M. D. Witter.
		MAINE.								
14	7 20	Calais	45 11	67 17	3	1	.....	Rumbling	Like coal through shute	U. S. Weather Bureau.
	7 20	Eastport	44 54	66 59	3	1	.....	Rumbling	Like coal through shute	U. S. Weather Bureau.
		TENNESSEE.								
17	16 45	Knoxville	35 56	83 58	5	1	0 03	Explosion	May have been dynamite on ice jam in river.	U. S. Weather Bureau.

TABLE 2.—*Instrumental seismological reports, January, 1918.*

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.]

[For significance of symbols, see REVIEW for January, 1918, p. 34.]

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat. 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants:

	V	T_0
E	10	16.6
N	10	15.4

(Report for January, 1918, not received.)

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat. 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants:

	V	T_0
E	10	14
N	10	19

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4	.....	eP_N	4 36 54	5	.....	.....	.....	
		eS_N	4 42 20	.....	.....	.....	.....	
		eL_N	4 46 32	.....	.....	.....	.....	
		eL_E	4 46 ..	.....	.....	.....	.....	
		M_N	4 47 13	6	.....	20	.....	
		M_E	4 47 26	8	30	.....	.....	
		F	5 04 ..	7	.....	.....	.....	
25	.....	e_E	1 25 38	.....	.....	.....	.....	No definite phases.
		e_N	1 26 07	.....	.....	.....	.....	
		M_E	1 36 00	7	60	.....	.....	
		M_N	1 39 01	6	.....	40	.....	
		F	2 13 ..	.....	.....	.....	.....	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 21	.....	.....	.....	.....	200	100	.....	Microseisms during 24 hours preceding 16 h. 0 min. (G. M. T.) on dates given.
27	.....	.....	.....	.....	200	300	.....	
28	.....	.....	.....	.....	100	100	.....	

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Colorado. *Denver. Sacred Heart College.* Earthquake Station.

A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

(No seismic disturbance was observed during the month.)

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin vertical pendulum, undamped. Mechanical registration.

Instrumental constants....110 6.4

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4	.....	P?.....	4 38 25	.....	.....	.....	.....	Microseisms present.
		S.....	4 43 05	.....	.....	.....	.....	
		L.....	4 45 45	24	.....	.....	.....	
		F.....	5 25 ..	.....	.....	.....	.....	
13	.....	S?.....	0 02 55	.....	.....	.....	.....	Microseisms present.
		L.....	0 04 00	.....	.....	.....	.....	
		F.....	0 15 ..	.....	.....	.....	.....	
25	.....	P.....	1 26 40	.....	.....	.....	.....	Microseisms present.
		S?.....	1 31 12	.....	.....	.....	.....	
		L.....	1 34 15	24	.....	.....	.....	
		F.....	2 15 ..	.....	.....	.....	.....	
30	.....	P.....	21 31 02	.....	.....	.....	8,750	
		S.....	21 41 00	.....	.....	.....	.....	
		L.....	22 01 00	.....	.....	.....	.....	
		F.....	22 40 ..	.....	.....	.....	.....	

District of Columbia. *Washington. Georgetown University.*

F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants:

	V	T_0	ε
E	165	5.4	—
N	143	5.2	—
Z	30	3.0	—

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4	.....	eP	4 37 02	.....	.....	.....	.....	Heavy microseisms. No distinct Main.
		S_N	4 42 31					
		eL_E	4 46 24	29				
		F	5 13 ..					
12	.....	e?	23 59 27	.....	.....	.....	.....	Heavy microseisms, e very uncertain.
13	.....	S	0 03 00	.....	.....	.....	.....	
		eL	0 03 54	7	.....	.....	.....	
		F	0 25 ..	.....	.....	.....	.....	
25	.....	e	1 26 38	.....	.....	.....	.....	Heavy microseisms, S doubtful.
		S_E	1 33 31	.....	.....	.....	.....	
		S_N	1 33 35	.....	.....	.....	.....	
		eL	1 37 12	16	.....	.....	.....	
		L	1 41 01	12	.....	.....	.....	
		F	2 20 ..	.....	.....	.....	.....	
30	.....	iP_N	21 31 01	.....	.....	.....	.....	Heavy microseisms. No distinct M. F lost in microseisms.
		eP_E	21 31 03	.....	.....	.....	.....	
		iS	21 41 00	.....	.....	.....	.....	
		L_E	22 01 14	24	.....	.....	.....	
		L_N	22 08 22	17	.....	.....	.....	
			VERTICAL		A_Z			
		iP	*21 31 05*	.....	.....	.....	.....	
		iS	*21 41 00*	.....	.....	.....	.....	
		L	*22 07 35*	*16*	.....	.....	.....	
		F	*22 17 ..*	.....	.....	.....	.....	

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neuman.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant..T_0 18.5

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*km.*	
1818. Jan. 4	.....	eP	4 52 00	.....	.....	.....	.....	
		eL	5 04 18	.....	.....	.....	.....	
		M	5 07 18	20	*500	.....	.....	
		F	5 43 ..	.....	.....	.....	.....	
4	.....	eP	16 03 48	.....	.....	.....	.....	
		eS	16 08 54	.....	.....	.....	.....	
		eL	16 11 48	23	.....	.....	.....	
		M	16 21 12	20	*400	.....	.....	
		C	16 34 ..	.....	.....	.....	.....	
		F	17 06 ..	.....	.....	.....	.....	
12	.....	e	18 54 24	.....	.....	.....	.....	
		M	19 05 00	19	*100	.....	.....	
		F	19 07 ..	.....	.....	.....	.....	
15	.....	e	16 04 36	25	.....	.....	.....	
		M	16 13 00	19	*300	.....	.....	
		C	16 19 ..	.....	.....	.....	.....	
		F	16 21 ..	.....	.....	.....	.....	
21	.....	e	20 20 24	.....	.....	.....	.....	Beginning and final phases lost in tremors due to rapid change in temperature.
		M	20 26 30	19	*1100	.....	.....	
		C	20 28 ..	.....	.....	.....	.....	
24	.....	e	15 08 30	.....	.....	.....	.....	
		M	15 13 00	.....	*200	.....	.....	
		F	15 40 ..	.....	.....	.....	.....	
25	.....	eS	1 39 54	.....	.....	.....	.....	
		eL	1 50 30	20	.....	.....	.....	
		M	1 54 42	24	*600	.....	.....	
		C	2 03 ..	.....	.....	.....	.....	
		F	2 41 ..	.....	.....	.....	.....	
30	.....	eP	21 28 12	.....	.....	.....	.....	
		S	21 36 00	.....	.....	.....	.....	
		eL	21 42 42	23	.....	.....	.....	
		M	21 44 00	20	*4400	.....	.....	
		C	21 48 ..	.....	.....	.....	.....	
		F	23 03 ..	.....	.....	.....	.....	

* Trace amplitude.

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants..

	V	T_0	ϵ
E	177	3.4	4:1
N	205	3.4	4:1

(Report for January, 1918, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..

	V	T_0
E	10	32
N	10	27

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*km.*	
1918. Jan. 4	.....	eS_N	4 42 58	.....	.....	.....	.....	
		eL_N	4 46 ..	.....	.....	.....	.....	
		eL_E	4 46 38	.....	.....	.....	.....	
		M_N	4 47 08	4	.....	10	.....	
		M_E	4 47 44	20	30	.....	.....	
		F	6 00 ..	.....	.....	.....	.....	
25	.....	eP_N	1 31 49	.....	.....	.....	.....	
		eP_E	1 32 10	.....	.....	.....	.....	
		eL_E	1 37 ..	.....	.....	.....	.....	
		M_E	1 38 20	8	50	.....	.....	
		M_N	1 39 10	8	.....	20	.....	
		F	1 56 ..	.....	.....	.....	.....	
30	.....	eP	21 31 06	.....	.....	.....	.....	
		M_N	21 41 10	.....	.....	10	.....	
		M_E	21 44 14	.....	10	.....	.....	
		F	21 59 ..	.....	.....	.....	.....	

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (Mechanical registration).

Instrumental constants....

	V	T_0	ϵ
E	80	23	0
N	50	25	4:1

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*km.*	
1918. Jan. 3	.....	*O*.....	16	.....	.....	.....	?	Record irregular, masked by microseisms and traffic jars.
		e_N.....	16 33 38	16	.....	.....	.....	
		L_N.....	16 39 57	20	.....	.....	.....	
		F.....	16 52 ca	.....	.....	.....	.....	
4	.....	*O*.....	4 29 55	.....	.....	.....	3,910	Destructive at Guatemala City.
		P_N.....	4 37 14	.....	.....	.....	.....	
		S_E.....	4 42 56	6	.....	.....	.....	
		eL_E...	4 46 59	40	.....	.....	.....	Undamped pendulum.
		M_E.....	4 49 43	26	.....	.....	.....	
		F.....	6 16 36	.....	.....	.....	.....	
12	.....	*O*?....	23 46 13	.....	.....	.....	3,914?	P masked by microseisms.
		S_E.....	23 59 07	.....	.....	.....	.....	
13	.....	S_N.....	0 00 14	6	.....	.....	.....	
		eL_N...	0 03 23	13	.....	.....	.....	
		L_E.....	0 03 43	6½	.....	.....	.....	
		L_N.....	0 03 46	6½	.....	.....	.....	
		L_N.....	0 05 52	6½	.....	.....	.....	
		M_E.....	0 06 12	9	.....	.....	.....	Undamped pendulums.
		M_N.....	0 06 18		.....	.....	.....	
		C_N.....	0 07 12	.....	.....	.....	.....	
		F_N?...	0 08 34	.....	.....	.....	.....	
13	.....	*O*?....	1	.....	.....	.....	?	Masked by microseisms.
		L_N?...	2 02 31	16	.....	.....	.....	
		L.....	2 03 21	16	.....	.....	.....	
		L.....	2 04 26	10	.....	.....	.....	
		F?.....	2 13 27	.....	.....	.....	.....	
14	.....	*O*iM...	4 47 28	.....	.....	.....	0	Frost crack at station. A. of trace =0.3 mm.
		C.....	4 47 29	.....	.....	.....	.....	
		F.....	4 47 32	.....	.....	.....	.....	
14	.....	*O*iM...	7 22 28	.....	.....	.....	0	Frost crack at station.
		C.....	7 22 29	.....	.....	.....	.....	
		F.....	7 22 36	.....	.....	.....	.....	
15	.....	*O*?....	23 35 ca	.....	.....	.....	4,900?	Doubtful record in microseisms.
		S_N?...	23 56 39	.....	.....	.....	.....	
		i.....	23 58 07	.....	.....	.....	.....	
16	.....	eL_N?..	0 03 10	16	.....	.....	.....	
		F?.....	1 42 ca	.....	.....	.....	.....	
16	.....	*O*?....	13	.....	.....	.....	.....	Doubtful record in microseisms.
		e_E?....	13 17 55	.....	.....	.....	.....	
		e.....	13 18 27	.....	.....	.....	.....	
		eL_E...	13 41 45	40	.....	.....	.....	
		L_N.....	13 43 23	20	.....	.....	.....	
		F?.....	14 30 ..	.....	.....	.....	.....	
25	.....	*O*?....	1 21 38	.....	.....	.....	4,600?	Much masked by microseisms.
		S_E?...	1 29 39	.....	.....	.....	.....	
		e_N.....	1 33 15	.....	.....	.....	.....	
		eL_N...	1 35 26	45?	.....	.....	.....	
		eL_E...	1 35 29	40	.....	.....	.....	
		M_E.....	1 37 54	25	.....	.....	.....	Undamped pendulum.
		M_N.....	1 41 37		.....	.....	.....	
		C_E.....	1 43 52	.....	.....	.....	.....	
		L_E?...	2 20 28	15	.....	.....	.....	
		F?.....	2 21 ca	.....	.....	.....	.....	
30	.....	*O*.....	21	.....	.....	.....	.....	Record lost in tangled lines of diurnal tilt.
		e_N.....	21 33 33	6	.....	.....	.....	
		e_N.....	21 40 34	16	.....	.....	.....	
		i_N.....	21 40 52	16	.....	.....	.....	
		i_N.....	21 42 19	18	.....	.....	.....	
		.....	21 43 00	16	.....	.....	.....	
		.....	21 48 31	.....	.....	.....	.....	
		L.....	21 57 42	.....	.....	.....	.....	
		F.....	23 36 ca	.....	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instruments: Wiechert, 80 kg. astatic, horizontal pendulum.

Instrumental constants.. V 80, T_0 7, ϵ 5:1

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 25	I.	P_E	1 26 42				1,400	Microseisms daily throughout the month.
		S_E	1 30 24					
		L	1 31 18	6				N–S masked by wind disturbances.
		L	1 35 36	9				
		L	1 38 48	6				
		L	1 40 24	6				
		L	1 41 12	6				
		F	1 50 ..					
30	I.	P_N	21 40 30					
		P_E	21 40 36					
		L_N	21 43 06			*6,000		F masked by microseisms.
		L_N	21 44 00			*6.000		

* Trace amplitude.

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert, 80 kg., horizontal.

Instrumental constants.. V 80, T_0 7, ϵ 5:1

(Report for January, 1918, not received.)

New York. *Fordham. Fordham University.* W. C. Repetti, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants.. V E 72, N 72; T_0 5, 5; ϵ 1.5:1, 3.8:1

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 25		eL	1 30 00					
		F	1 44 ..					
30		ePg	21 36 24					Magnified by resonance with microseisms.
		iP_N	21 36 24					
		eL_E	21 50 ca	20				
		L_N	21 55 ca					S not discernible.

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants.. V E 13, N 14; T_0 22, 25; ϵ 4:1, 4:1

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4		eL	4 46 56	30				
		F	5 02 ..					
25		e_N	1 32 24	8				
		L_N	1 36 36	23				
		F	2 10 ..					
30		e_N	21 35 ..					Possibly not seismic.
		i_E	21 40 54	4				
		F_N	22 22 ..					

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Panama Canal. *Balboa Heights.* Governor, Panama Canal.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants.. V 10, T_0 20

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4		P_E	4 35 36				1,127	Probable direction NW.
		P_N	4 35 44					
		L_E	4 38 58					
		L_N	4 39 04					
		M_E	4 35 40	20	*1,500			
		M_E	4 40 22	20		*500		
		F_N	4 58 50					
		F_E	4 59 30					
8		M_E	9 13 48	20	*100			
		M_N	9 14 00	20		*200		
25		P_E	1 23 56				1,255	Probable direction NW.
		P_N	1 24 00					
		L_E	1 27 44					
		L_N	1 27 48					
		M_E	1 24 01	20	*4,000			
		M_N	1 24 04	20		*100		
		F_N	1 55 00					
		F_E	1 57 00					
26		L_E	18 01 20					P uncertain.
		L_N	18 01 25					
		M_N	18 01 28	20		*1,200		F uncertain.
		M_E	18 01 30	20	*2,200			
29		M	0 04 20	20	*100	*100		P, S, L, and F uncertain.

* Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 08′ 48″ N.; long., 65° 26′ 54″ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.. V E 10, N 10; T_0 18, 18

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4		ePg	4 36 53					
		eL_N	4 42 16					
		eL_E	4 42 21	18				
		M_N	4 48 05	17		20		
		M_E	4 48 50	18	60			
		C	4 54 ..	17				
		F	5 03 ..	12				
16		eL	13 33 ..	14				
		M_N	13 35 20	12		10		
		M_E	13 37 15	12	20			
		F	13 57 ..					
25		ePg	1 25 20	4				
		eP_N	1 25 35					
		eS_N	1 29 35					
		eL_E	1 32 15	20				
		eL_N	1 32 20	20				
		M_E	1 35 20	18	50			
		M_N	1 36 15	15		20		
		C	1 42 ..	16				
		F	1 57 ..					

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants.. V E 10, N 10; T_0 15, 16

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4		e	4 43 ..					Phases indistinct.
		eL	4 49 ..					
		F	5 10 ..					
13		e	0 02 ..					
		F	0 10 ..					
25		e	1 29 ..					Phases lost whi changing sheet
		F	2 00 ..					
30		P	21 30 52				8,490	
		S	21 40 3[illegible]					
		F	22 10 ..					

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer, 80 kg. vertical seismograph.

Instrumental constants: V 120, T_0 26.

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4	.....	eS?$_N$	4 43 44	.....	.....	.....	.....	
		eL$_N$	4 46 30†	.....	.....	.....	.....	
		L	4 49 ..	24	.....	.....	.....	
		L$_N$	4 54 to	.....	.....	.....	.....	
		F	5 20 ..	.....	.....	.....	.....	Irregular periods mingled with microseisms.
13	.....	e$_E$	0 00 00	3	.....	.....	.....	
		e$_N$	0 00 38	4	.....	.....	.....	
		eL$_N$	0 01 04	6	.....	.....	.....	
		M	0 03 36†	7	.....	.....	.....	
		F	0 10 ..	.....	.....	.....	.....	
25	.....	*O*	1 21 32	ca.	.....	.....	3,600ca	Δ from eL-P. No trace of S. Heavy microseisms.
		P$_E$	1 28 20	2	.....	.....	.....	
		e	1 35 48†	2	.....	.....	.....	
		eL$_E$	1 37 24	28	.....	.....	.....	
		L	1 41 ..	22	.....	.....	.....	
		F	2	.....	.....	.....	.....	
30	.....	*O*	21 18 46	.....	.....	.....	8,560	
		iP	21 30 36	.....	.....	.....	.....	
		iS	21 40 24	.....	.....	.....	.....	
		i	21 42 12	.....	.....	.....	.....	
		eL	21 56 30†	28	.....	.....	.....	
		L	22 05 ..	18	.....	.....	.....	
		L$_N$	22 09 ..	15	.....	.....	.....	
		L$_N$	22 20 ..	15	.....	.....	.....	
		F	.. .. ..	22–35	.....	.....	.....	

† Original time was in tenths of a minute.

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North. In the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom=0.59″.

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4	.....	eL	4 47 36	.....	.....	.....	.....	P and S not recorded.
		eL	4 49 24	.....	.....	.....	.....	
		iL	4 50 00	.....	.....	.....	.....	
		M	4 50 42	.....	*1,800	.....	.....	
		F	5 26 18	.....	.....	.....	.....	
4	.....	eL	16 55 18	.....	.....	.....	.....	Distant quake. Marked gradual thickening.
		M	17 04 00	.....	*600	.....	.....	
		F	17 35 48	.....	.....	.....	.....	
12	.....	L	23 34 12	.....	*100	.....	.....	Air currents going on.
			23 36 54	.....	.....	.....	.....	
13	.....	L	0 04 36	.....	*200	.....	.....	Air currents going on.
			0 12 24	.....	.....	.....	.....	
16	.....	L	13 46 30	.....	.....	.....	.....	May not be seismic.
		eL	13 51 24	.....	.....	.....	.....	
		M	13 55 48	.....	*300	.....	.....	
		F	14 23 12	.....	.....	.....	.....	
21	.....	L	20 54 06	.....	.....	.....	.....	
		L	20 58 06	.....	.....	.....	.....	
		M	21 04 48	.....	*100	.....	.....	
		F	21 23 00	.....	.....	.....	.....	
24	.....	eL	15 42 48	.....	.....	.....	.....	Gradual thickening.
		e	15 46 54	.....	.....	.....	.....	
		eL	15 50 18	.....	.....	.....	.....	
		M	15 54 12	.....	*200	.....	.....	
		F	16 30 54	.....	.....	.....	.....	
25	.....	P?	1 25 36	.....	.....	.....	.....	Air currents going on.
		e	1 29 48	.....	.....	.....	.....	
		eS	1 34 00	.....	.....	.....	.....	
		eL	1 37 12	.....	.....	.....	.....	
		iL	1 37 48	.....	.....	.....	.....	
		iL	1 40 54	.....	.....	.....	.....	
		M	1 41 54	.....	*2,400	.....	.....	
		F	.....	.....	.....	.....	.....	"A. C."
30	.....	iS	21 41 36	.....	.....	.....	.....	P not definite. Amplitude of S waves gradually became less. "A. C."
		M	21 41 48	.....	*1,700	.....	.....	
		L	21 59 18	.....	.....	.....	.....	
		L	22 07 00	.....	.....	.....	.....	
		F	.....	.....	.....	.....	.....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instruments: Wiechert, vertical. Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. T_0 18. Pillar deviation: 1 mm. swing of boom=0.54″.

1918.			H. m. s.	Sec.	μ	μ	km.	
Jan. 4	.....	S?.....	4 46 01	.....	.....	.....	.....	
		L.....	4 50 02	.....	.....	.....	.....	
		L.....	4 56 22	.....	.....	.....	.....	
		M.....	5 03 08	.....	*1,000	.....	.....	
		F.....	5 29 43	.....	.....	.....	.....	
			VERTICAL.		A_Z			
		M.....	*5 01 30*	*18*	*1*	.....	.....	
4	.....	P.....	16 26 13	.....	.....	.....	.....	
		L.....	16 35 04	.....	.....	.....	.....	
		M.....	16 39 00	.....	*400	.....	.....	
		F.....	17 02 37	.....	.....	.....	.....	
12	.....	P or L	23 48 49	.....	.....	.....	.....	
		M.....	23 50 18	.....	*200	.....	.....	
21	.....	P? or L	20 30 21	.....	.....	.....	.....	
		L?.....	20 39 12	.....	.....	.....	.....	
		M.....	20 47 18	.....	*300	.....	.....	
		F.....	21 05 46	.....	.....	.....	.....	
24	.....	P?.....	15 40 12	.....	.....	.....	.....	
		M.....	15 43 39	.....	*100	.....	.....	
		F.....	15 48 04	.....	.....	.....	.....	
25	.....	P or S?	1 35 35	.....	.....	.....	.....	Trace indistinct.
		L?.....	1 40 03	.....	.....	.....	.....	
		L.....	1 45 30	.....	.....	.....	.....	
		M.....	1 48 28	.....	*500	.....	.....	
		F.....	2 18 13	.....	.....	.....	.....	
30	.....	P?.....	21 23 30	.....	.....	.....	.....	Vertical record ill-defined.
		S?.....	21 28 32	.....	.....	.....	.....	
		L?.....	21 33 59	.....	.....	.....	.....	
		i.....	21 37 16	.....	.....	.....	.....	
		M.....	21 37 46	.....	*500	.....	3,270	
		L$_{rep}$...	22 18 34	.....	.....	.....	.....	
		F.....	22 23 00	.....	.....	.....	.....	

* Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Geneva, January 3, 1918.

The Zurich observatory reports that a serious earthquake which was recorded recently has been located at Oberammergau, in upper Bavaria, and also in the upper valley of the Lech River. (Associated Press.)

Washington, D. C., January 4, 1918.

The entire city of Guatemala was wiped out by an earthquake shock Friday night (Jan. 4) at 10.45 o'clock. (Radio dispatch from Darien to the War Department.)

Washington, D. C., January 5, 1918.

Our manager at San Jose, Guatemala, telegraphs the following: "What was left of Guatemala City is now wiped out. Shocks at 10.35 p. m. finished everything. Steam is now coming up in the streets. Cathedral fallen; 300 killed." (Dispatch from the Central and American Telegraph Co.)

Guatemala City, January 5, 1918.

The earthquakes here continue with varying frequency and intensity. The capitol is in ruins. (Associated Press.)

Washington, D. C., January 27, 1918.

Further severe earthquake shocks in Guatemala City, capital of Guatemala, were reported yesterday to the State Department by the American legation there. No details of the extent of the damage were given.

Extensive damage was done to the city by earthquakes last month. (State Department.)

[1] Reported by the organization indicated and collected by the seismological station of Georgetown University, Washington, D. C.

SECTION VI.—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

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Anuario meteorológico de Chile. Segunda parte (Resúmenes) 1915. Santiago de Chile. 1917. p.l., 128 p. 2 l., incl. tables, 36½cm. [Publication] no. 22.

Dessoliers, Hippolyte.
System of producing heat-rains by means of sheets of water of slight depth. 3 p. 29cm. (U. S. Patent office. Specification of letters patent. 1,252,670. Application filed June 20, 1914. No drawing. Serial no. 846,410. Patented Jan. 8, 1918.)

Lourenço Marques. Observatório Campos Rodrigues.
Rélatório. Ano de 1916. Volume 8. Lourenço Marques. 1917. 181 p. incl. tables. 38½cm. At head of title: Província de Moçambique. Serviços de marinha.

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Seeley, Dewey Alsdorf.
Relation between temperature and crops. plate. 17 tables. 2 charts. 23cm. (Reprinted from 19th report. Michigan academy of science. 1917. p. [167]–196.) [Literature cited, p. 194–195].

Slipher, V[esto] M[elvin].
The spectrum of lightning. [Flagstaff, Ariz. Sept. 1917.] 32cm. (Lowell observatory. Bulletin no. 79. p. 55–58.)

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Bijdrage tot de Kennis van het klimaat van Nederland. [Parts 1–5.] [De Bilt] 1916–1917. plate. tables. charts. 25cm. (Overgedrukt uit det "Tijdschrift van het K. Nederlandsch aardrijkskundig genootschap," 2e Ser. dl. 33, 1916, Afl. 1, 2, 6, p. 1–29; 163–190; 827–845. dl. 34, 1917, Afl. 4, 6, p. 481–504; 800–821.)

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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Forest investigators. Proceedings of meeting. Washington. February 26–March 2, [1917].
Mitchell, J. A. Temperatures—air and soil [in forestry]. p. 170–178.
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[Washington, D. C., Feb. 26, 1918.]

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SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF JANUARY, 1918.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Climatological Division, Weather Bureau, Mar. 2, 1918.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for January, 1918, are shown graphically on Chart VII (XLVI—7), while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

At the beginning of the month the pressure was relatively high from the New England States to the lower Lakes Region and thence southwestward to the western Gulf; also in the central and southern Plateau region. It was lower than normal from the upper Mississippi Valley westward to the Rocky Mountains, but elsewhere was near the seasonal average. During the next few days lower pressure overspread most portions of the country and continued during much of the first decade. During the second decade extensive low-pressure areas rapidly crossed the country, and while they were followed in turn by areas of higher pressure, the averages during this period were below the normal over most sections. During the remainder of the month rapid changes in pressure continued, but the high areas were more pronounced than during the preceding decade and the prevailing pressure over most sections during much of this period was above the normal. The month closed with pressure above the normal from the Rocky Mountains eastward, except in the extreme eastern Canadian Provinces, but to the westward it was below the seasonal average.

For January as a whole the barometric pressure was slightly above the normal in the Upper Missouri Valley, the northwestern Canadian Provinces, and over the western portions of the Pacific Coast States. In all other sections it was below the seasonal average, the negative departure being rather pronounced east of the Mississippi River and particularly so in the far Northeast.

The distribution of the HIGHS and LOWS resulted in prevailing southwesterly to northwesterly winds in most sections east of the Rocky Mountains, except in the Southwest, where they were generally northerly. West of the Rocky Mountains variable winds prevailed. While the month was characterized in many sections by marked abnormal weather conditions, the prevailing wind directions were not unusual. In fact, they conformed remarkably to the usual seasonal directions.

TEMPERATURE.

January opened with a damaging cold wave over the Southern States, which caused freezing weather to the Gulf and heavy frost as far south as Miami, Fla. After a few days of slightly higher temperature cold weather again overspread the East and Southeast, causing freezing temperatures nearly to extreme southern Florida, while portions of Virginia experienced the lowest temperatures ever recorded there in January. In marked contrast, the maximum temperatures during this period in portions of Utah and Idaho were the highest ever recorded in those sections during January.

Cold weather continued over many portions of the East, and at the beginning of the second decade another cold wave moved from the Northwest southeastward, causing the lowest temperatures ever recorded at points in Texas. During the next few days the cold was more intense than had been experienced in January during many years, over central and southern districts. Temperatures were somewhat less severe in the Northeastern than in the Central States, but the weather continued cold in most eastern districts throughout the second decade.

Early in the third decade the temperature was again below freezing in extreme southern Texas and while there was a gradual warming up in the Southeast most other sections east of the Rocky Mountains experienced unusually cold weather until the close of the month, at which time temperatures of from 20 to nearly 40 degrees below zero (F.) were experienced in the northern Great Plains Region.

For January, as a whole, the temperature was below the normal, as during the preceding month, in all districts east of the Rocky Mountains, the deficiencies reaching more than 12 degrees per day in portions of the Central Mississippi and lower Ohio valleys. In portions of the above region the month was continuously the coldest of which there is record. At Portsmouth, Ohio, where reliable records exist since 1824, the average temperature for January, 1918, is the lowest observed during the period of nearly 100 years. The only years with temperatures closely approaching those of January, 1918, were January, 1856 and 1857, two remarkably cold months over all eastern parts of the United States, but apparently 2 or 3 degrees warmer than the present January.

Over the southern Canadian Provinces, the month was warmer than is usual for January as far east as Manitoba, and only slightly colder than normal to the eastward; the temperature deficiencies were less marked than to the southward over the central and eastern districts of the United States.

West of the Rocky Mountains most districts had monthly mean temperatures warmer than usual, particularly in the more northern districts where, like December, 1917, the whole month was unusually warm.

Maximum temperatures of about 80° were reached at a few places in the South and Southwest; but in portions of the upper Lakes Region and westward as far as North Dakota, the temperature did not rise above freezing at any time during the month. Even as far south as Missouri, there were only a few days with temperatures as high as 32°.

The lowest temperature reported from a regular Weather Bureau Station, was −38° at Havre, Mont., although temperatures between −40° and −50° were reported from the country districts in portions of the northern border States. Temperatures fell to 0°F. or lower in all central and northern districts, and freezing weather occurred throughout Texas and nearly to the extreme southern limit of Florida, but did not reach central or western California. In some of the northern States, particularly in the Upper Lakes Region, there were only a few days during the month when 0° was not recorded in some portion of the States, while the highest was rarely above freezing.

PRECIPITATION.

The month opened with generally fair weather except in the upper Lakes Region, where light snow prevailed, but this area of precipitation rapidly overspread much of the eastern portion of the country. After a few days of comparatively fair weather, rain occurred in the far South and thereafter snow or rain fell at frequent intervals in many sections of the country east of the Mississippi River. The storms moved rapidly across the country and gave, on the whole, moderate precipitation, although the amounts were heavy in some localities. Toward the latter part of the month extensive and heavy snows occurred in most eastern sections.

Light rains occurred nearly every day during the month in the North Pacific States, and about the middle of the month rather general precipitation occurred over most sections west of the Rocky Mountains.

For the month, as a whole, the precipitation was near the normal in the States east of the Mississippi, with a moderate excess in portions of the Southeast. The monthly totals were rather large, but generally less than normal in the North Pacific States; while in California, Nevada, and portions of adjoining States there was very little precipitation and, as the preceding months had been dry, the accumulated deficiency at the end of January had become unusually large. Over the Great Plains and the States next west of the upper Mississippi River, the precipitation was scanty, and in portions of Texas severe drought still continued.

The total snowfall for January, like that of the preceding month, was much heavier than usual in the central districts from the Mississippi Valley eastward. The falls were particularly heavy from the southern end of Lake Michigan southward and southeastward over the Ohio Valley; and likewise from southwestern Virginia northeastward to and including Pennsylvania, where the monthly totals ranged from 1 to 2 feet or more. From the central Mississippi Valley eastward, the total snowfall was 2 to 4 times as much as is usually recorded in January. High winds caused much drifting of the snow in some of the large business districts, which greatly interfered with outdoor occupations, railway traffic, and other forms of transportation.

RELATIVE HUMIDITY.

For the month as a whole the atmosphere was relatively drier than usual for January throughout most of the coastal portions of the Atlantic and Gulf States and also in central California, Nevada, and western Utah. Elsewhere the relative humidity was generally above the normal, although in many small irregularly distributed areas it was lower than the seasonal average.

GENERAL SUMMARY.

The weather during January, 1918, was decidedly unfavorable for outdoor activities in all sections of the country east of the Rocky Mountains. This was particularly true for the central and northern districts east of the Mississippi, where severe cold and frequent heavy snows prevented practically all farm operations, greatly hindered railroad and other transportation, delayed mining operations, and caused much suffering and inconvenience in the large cities from lack of fuel and other necessary supplies.[1]

[1] Traffic delays, due to snow blockades, served to aggravate those of non-meteorological origin.—C. A., jr.

In the Pacific Coast States, where mild weather prevailed, farm work progressed favorably and vegetation advanced more rapidly than usual, except where drought continued.

In the Southern States farm work was backward and vegetation made but little progress on account of the continued cold. Tender crops were generally killed by the low temperatures and hardy vegetables were damaged in nearly all districts except in southern Florida. Plowing for corn and cotton made some progress in the more southern portions.

Winter wheat was well covered with snow throughout the month from the Mississippi Valley eastward and from Tennessee and North Carolina northward. There was likewise a good snow cover in portions of Montana and the greater part of Missouri. In Kansas and Oklahoma considerable snow fell, but it drifted badly leaving much ground bare, and the condition of the wheat in the western portions of those States continued poor. The weather was more favorable for winter grains in the Rocky Mountains Region, and in the northern Pacific Coast States the mild, moist weather was very beneficial; these crops made rapid progress and were generally in fine condition.

Some citrus fruit trees were damaged by the cold weather in the central and western Gulf region and a few young trees were killed in Florida. Deciduous fruit buds were apparently not damaged in the Southeastern States, but in some parts of the Mississippi Valley and northeastern districts the unusually low temperatures doubtless killed or greatly damaged the peach buds.

A more extensive review of the severe weather during the month of December, 1917, and January, 1918, will appear in an early issue of the REVIEW.

Average accumulated departures for January, 1918.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	Ins.	Ins.	Ins.	0-10.		P. ct.	
New England	17.0	− 7.4	− 7.4	2.75	−0.80	−0.80	5.9	−0.1	75	− 1
Middle Atlantic	22.7	− 8.9	− 8.9	4.06	+0.70	+0.70	5.9	−0.1	73	− 3
South Atlantic	38.6	− 6.6	− 6.6	2.76	−1.00	−1.00	5.2	−0.1	76	− 1
Florida Peninsula	61.8	− 2.7	− 2.7	1.63	−1.10	−1.10	3.8	−1.0	78	− 4
East Gulf	41.3	− 6.1	− 6.1	6.77	+1.30	+1.30	5.6	−0.1	69	− 8
West Gulf	38.7	− 7.4	− 7.4	1.72	−1.20	−1.20	4.3	−1.1	71	− 4
Ohio Valley and Tennessee	21.1	−12.1	−12.1	4.55	+0.70	+0.70	6.7	+0.2	82	+ 5
Lower Lakes	13.4	−10.4	−10.4	2.88	+0.20	+0.20	6.8	−0.7	83	+ 3
Upper Lakes	8.5	− 9.8	− 9.8	2.56	+0.60	+0.60	6.9	−0.1	85	+ 3
North Dakota	− 1.1	− 5.2	− 5.2	0.56	0.00	0.00	6.4	+1.4	88	+ 7
Upper Mississippi Valley	10.7	−10.8	−10.8	1.38	−0.30	−0.30	5.3	−0.3	83	+ 3
Missouri Valley	12.6	− 8.5	− 8.5	0.95	0.00	0.00	5.5	+0.4	83	+ 6
Northern slope	16.1	− 2.9	− 2.9	1.18	+0.30	+0.30	6.5	+1.3	78	+ 5
Middle slope	21.4	− 7.8	− 7.8	0.78	+0.10	+0.10	4.8	+0.5	74	+ 6
Southern slope	34.4	− 4.8	− 4.8	0.68	0.00	0.00	3.6	−0.9	61	− 3
Southern plateau	40.1	− 0.7	− 0.7	1.03	+0.10	+0.10	2.9	−0.6	52	0
Middle plateau	30.0	+ 1.5	+ 1.5	1.10	0.00	0.00	4.9	−0.5	66	− 6
Northern plateau	33.1	+ 4.3	+ 4.3	2.20	+0.60	+0.60	7.7	+0.8	80	0
North Pacific	44.8	+ 4.7	+ 4.7	6.13	−0.80	−0.80	8.1	+0.5	85	− 1
Middle Pacific	49.2	+ 1.9	+ 1.9	1.13	−3.60	−3.60	4.3	−1.6	70	−11
South Pacific	52.6	+ 1.7	+ 1.7	0.79	−2.00	−2.00	3.8	−0.9	67	− 4

WEATHER CONDITIONS OVER THE NORTH ATLANTIC OCEAN DURING JANUARY, 1917.

The data presented are for January, 1917, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month. Chart IX (XLVI–9) shows for January, 1917, the principal storm tracks, the averages of pressure, air temperature, and for the first time the water surface temperatures (green), also the prevailing direction of the wind at 7 a. m., 75th meridian time (Greenwich mean noon). Notes on the locations and courses of the more severe storms of the month are included in the following general summary.

PRESSURE.

The mean atmospheric pressure for the month was unusual in some respects, especially south of the 40th parallel, as there was no well defined North Atlantic or Azores HIGH, although the isobar of 30.1 inches inclosed a long, narrow area extending from Madeira Island to eastern Texas. The southern portion of a LOW of 29.58 inches, central near latitude 55°, longitude 47°, is shown on Chart IX, and a second depression of slight intensity extended over France, and the southeastern part of England. The gradients over that part of the Atlantic Ocean east of the 40th meridian, were somewhat less than usual, while over the western division they were slightly steeper.

On January 14 a vessel near latitude 44°, longitude 55°, recorded a barometric reading of 31.03 inches, which is one of the highest ever reported over the ocean. This record was confirmed by those from a number of other vessels in the vicinity, where readings varied from 30.96 inches to 30.99 inches. The following table gives for a number of selected 5-degree squares the average pressure for each of the three decades of the month, as well as the highest and lowest individual readings reported within the respective squares.

Pressure over the North Atlantic Ocean during January, 1917, by 5-degree squares.

Position of 5-degree squares.		Decade means.			Extremes.			
					Highest.		Lowest.	
Latitude.	Longitude.	I.	II.	III.[a]	Pressure.	Date.	Pressure.	Date.
°	°	*Inches.*	*Inches.*	*Inches.*	*Inches.*		*Inches.*	
60–65 N.	20– 25 W.	29.83	29.90	29.88	30.52	Jan. 13	29.33	Jan. 16.
60–65 N.	5– 10 E.	29.65	30.06	30.40	30.80	Jan. 20	29.42	Jan. 4, 7.
55–60 N.	35– 40 W.	29.86	29.77	29.34	30.52	Jan. 13	29.00	Jan. 24.
55–60 N.	10– 15 W.	29.84	29.98	30.00	30.40	Jan. 23	29.58	Jan. 3.
55–60 N.	0– 5 E.	29.67	29.94	30.31	30.63	Jan. 20	29.30	Jan. 4, 11.
50–55 N.	55– 60 W.	29.75	29.59	29.56	30.60	Jan. 14	28.95	Jan. 31.
50–55 N.	30– 35 W.	29.99	29.83	29.31	30.52	Jan. 13	28.56	Jan. 24.
50–55 N.	0– 5 W.	29.89	29.79	30.07	30.40	Jan. 20	29.44	Jan. 12.
45–50 N.	65– 70 W.	29.77	29.95	30.01	30.60	Jan. 13	29.30	Jan. 6.
45–50 N.	50– 55 W.	29.82	29.69	29.54	30.78	Jan. 14	28.76	Jan. 31.
45–50 N.	25– 30 W.	30.21	29.95	29.42	30.48	Jan. 11	28.90	Jan. 24.
40–45 N.	55– 60 W.	29.88	30.03	29.86	31.03	Jan. 14	29.20	Jan. 19.
40–45 N.	15– 20 W.	30.39	29.94	29.66	30.53	Jan. 1	29.32	Jan. 27.
35–40 N.	75– 80 W.	29.97	30.24	30.10	30.70	Jan. 15	29.60	Jan. 11.
35–40 N.	50– 55 W.	29.86	30.16	29.97	30.77	Jan. 14	29.60	Jan. 19.
35–40 N.	35– 40 W.	30.11	30.10	29.88	30.57	Jan. 12	29.70	Jan. 30.
35–40 N.	5– 10 W.	30.22	29.88	29.81	30.37	Jan 1, 2	29.27	Jan. 27.
30–35 N.	40– 45 W.	30.03	30.16	30.03	30.52	Jan. 13	29.79	Jan. 30.
25–30 N.	95–100 W.	30.06	30.24	30.01	30.40	Jan. 17	29.76	Jan. 4.
20–25 N.	45– 50 W.	30.06	30.19	30.10	30.27	Jan. 13	30.02	Jan. 5, 7, 8.
15–20 N.	85– 90 W.	30.02	30.08	30.02	30.11	Jan. 16	30.00	Jan. 5,11,15.
15–20 N.	30– 35 W.	30.06	30.09	30.03	30.23	Jan. 18	30.00	Jan. 15, 28.

[a] Mean of last 11 days of the month.

The mean and extreme values presented in the above table are based on the daily pressures, determined by interpolation, of each square on the M. S. daily synoptic charts of the North Atlantic compiled by the Marine Section of the Weather Bureau.

GALES.

The number of gales reported during the month was below the normal over the entire ocean, with the exception of a small area immediately east of the Banks of Newfoundland, where they were somewhat more numerous than usual.

On January 1, a LOW of limited extent was central near latitude 44°, longitude 40°. The lowest barometric reading was 29.33 inches, and southwesterly gales of from 50 to 55 miles an hour were encountered by vessels a short distance south of the center. On the 2d and 3d the conditions over the entire ocean were featureless, with no disturbance of any consequence. On Chart III (XLV—3) "Tracks of Low Areas for January, 1917," a LOW (*I* on our Chart IX) is shown on the evening of January 1, near Edmonton, Alberta. This moved in a southeasterly direction with a uniform rate of translation, and on the evening of the 3d was about 150 miles east of New York. On the morning of the 4th, the center was near latitude 40°, longitude 64°, where the barometer read 29.44 inches, and moderate winds prevailed. The disturbance continued its easterly course, and on the 5th was central near latitude 37°, longitude 50°; it had increased in extent and diminished in intensity, the wind velocities remaining about the same as on the previous day. During the next 24 hours this area remained practically stationary, gradually filling in. On the 6th a LOW (*II* on Chart IX) was in the vicinity of Father Point, Quebec; the lowest barometric reading was 29.26 inches, and one vessel about 100 miles south of Halifax encountered a southerly gale of about 50 miles an hour. Low *II* moved rapidly on a due easterly course, and on the 7th, the center was a short distance east of St. Johns, N. F., the conditions of wind and weather having changed but little since the previous day. This disturbance then curved slightly toward the north, and on the 8th was central near latitude 51°, longitude 40°, moderate winds and fog prevailing between the 35th and 45th meridians. There was also on the 8th a LOW of marked intensity over the English Channel, the barometer readings at Calais and Dover being 28.87 inches. At the same time the Azores HIGH was unusually well developed, with the barometer at Ponta Delgada reading 30.41 inches. In consequence of the steep gradient between these areas strong northwesterly gales were prevalent off the coasts of France and Great Britain. During the next 24 hours the easterly drift of the LOW was slight, as on the 9th the center was apparently a short distance east of Calais. The barometer, however, had risen to 29.31 inches, and no reports of heavy winds were received. On the 10th and 11th a LOW surrounded the Canadian and New England coasts, moderate to strong gales prevailing on both days, and on the 11th two vessels as far south as the coast of Florida reported westerly winds of 40 miles an hour. On the 12th a LOW was central off the northern coast of Newfoundland, and a number of vessels between the 35th and 45th parallels, and the 60th meridian and the American coast, recorded westerly and northwesterly winds of from 30 to 64 miles an hour, the latter velocity being reported by a vessel about 200 miles east of Hatteras.

On the 14th there was a LOW over the greater part of Canada, while at the same time a HIGH with a crest of 31.03 inches was about 10 degrees east of Halifax. Northerly gales with hail prevailed in the easterly quadrants of this high area, between the 40th and 47th meridians where the barometer readings ranged from 30.31 to 30.66 inches. There also were winds of gale force between the 70th meridian and the American

coast, and the 41st and 37th parallels. On the 16th there was a disturbance apparently central not far from the south coast of Greenland, although its position could not be accurately located on account of lack of observations. In connection with this LOW, strong gales with snow and hail swept a limited area between the 43d and 53d parallels, and the 35th and 55th meridians, with a maximum velocity of 75 miles an hour near latitude 45° longitude 45°. On the 17th the center of this LOW was at latitude 53°, longitude 39°, heavy weather still prevailing in the southerly and southwesterly quadrants.

The disturbance moved but little during the next 24 hours, and on the 18th the weather conditions were about the same as on the previous day. On the 19th St. Johns, N. F., with a barometric reading of 28.94 inches, was the center of a well-developed LOW, westerly winds of from 40 to 65 miles an hour blowing over the region between the 35th and 44th parallels and the 50th and 70th meridians. From the 20th to the 23d the center of the disturbance remained between the 50th and 55th parallels and the 35th and 45th meridians. Moderate to strong gales were encountered on all these dates within the southern quadrants, and on the 22d, the storm area had reached its greatest extent, winds of 50 miles an hour occuring between the 28th and 45th meridans, from the Azores on the south to the 50th parallel on the north. On the 24th the LOW was near latitude 52°, longitude 32°, the lowest barometric reading being 28.60 inches; the winds had increased in force, and the greater part of the steamer lanes were swept with violent gales, accompanied by snow and hail.

By January 25 the conditions had moderated somewhat, although heavy winds still prevailed along the sailing routes, between the 30th and 45th meridians. From the 26th to the 29th there were a number of comparatively slight depressions distributed over the ocean, and gales of varying velocities were reported from many scattered localities. They were most severe and covered the largest area on the 26th, when a number of vessels northwest of the coast of Scotland, encountered southerly winds of from 40 to 75 miles an hour. There was also on the same day an extensive storm area in mid-ocean between the 40th and 55th meridians. On the 30th the most pronounced area of low pressure of the month was central near latitude 45°, longitude 37°, where the barometer reading was 28.60 inches. The gradients were unusually steep, and the cyclonic movement of the wind very marked, velocities of from 50 to 90 miles an hour being reported from a large area between the 35th and 52d parallels, and the 30th and 50th meridians. This LOW moved in an easterly direction, decreasing in intensity, and on the 31st the center was near latitude 45°, longitude 23°, where the barometer read 29.55 inches. On the same day a second LOW appeared about 200 miles northeast of St. Johns, N. F., and the greater part of this region between the two areas was swept by heavy gales, and snow was reported by a few vessels.

AIR TEMPERATURES.

The average temperature of tle air during the month was considerably above the normal over the greater part of the ocean; the departures ranged from 0 to +3 degrees in mid-ocean, from +6 to+9 degrees over the waters adjacent to the American coast and in the Gulf of Mexico, and from −1 to +4 along the European coast, while in the Northeast Trade Winds region they were either zero or slightly negative. In northern waters the average temperature for the first decade was above that of the last two; off the coast of Labrador the variation from day to day was comparatively large, and the extreme temperatures in that vicinity ranged from 15° on the 28th, to 36° on the 6th to the 9th, inclusive.

The following table gives the temperature departures for the month at a number of Canadian and United States Weather Bureau stations on the Atlantic and Gulf coasts.

	°F.		°F.
St. Johns, N. F.	−2.5	Norfolk, Va.	+2.4
Sydney, C. B. I.	−0.6	Hatteras, N. C.	+2.0
Halifax, N. S.	+0.6	Charleston, S. C.	+5.3
Eastport, Me.	+0.5	Key West, Fla.	+3.8
Portland, Me.	+0.4	Tampa, Fla.	+8.4
Boston, Mass.	+3.2	Mobile, Ala.	+7.4
Nantucket, Mass.	−0.7	New Orleans, La.	+6.8
Block Island, R. I.	+0.6	Galveston, Tex.	+3.9
New York, N. Y.	+2.2	Corpus Christi, Tex.	+4.8

WATER SURFACE TEMPERATURES.

In winter, the temperature of the water at the surface, is, as a rule, considerably above that of the air at the same place, while the fluctuations from day to day and departures from normal are both less. For the month under discussion the water temperatures were somewhat below the normal over practically the entire ocean. The greatest negative departure, about 4 degrees, occurred in the 5-degree square adjacent to the coasts of North and South Carolina. The greatest variation during the month was reported from the 5-degree square that includes St. Johns, N. F., where the water thermometer read 40° F. on the 8th, and 19° on the 28th.

FOG.

The number of days on which fog was reported was considerably less than usual over the northern division of the ocean, and in the vicinity of the Banks of Newfoundland, where the normal percentage is from 30 to 35, it was observed during January, 1917, on only 4 days or 14 per cent. It was reported on from 1 to 3 days along the steamer routes, and on 2 days in the vicinity of Nantucket Shoals, while the European coast was practically free of fog.

HAIL AND SNOW.

The most frequent occurance of hail was in the 5-degree square between latitudes 45°—50°, longitudes 35°—40°, where it was reported on 8 days. It was not observed on more than one day in any square east of the 30th meridian, or along the American and European coasts.

Snow occurred less frequently than hail, over the ocean as a whole; the greatest number of days on which it was observed was 7, in the square between latitudes 40°—45°, longitudes 55°—60°.

Winds of 50 miles per hour (22.4 m./sec.) or over, during January, 1918.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
		Mls./hr.				*Mls./hr.*				*Mls./hr.*		Point Reyes Light, Cal.—Continued.		*Mls./hr.*	
Atlanta, Ga	11	60	sw.	Ellendale, N. Dak.—Continued.				Mount Tamalpais, Cal.—Continued.				Do	14	52	se.
Do	15	54	w.	Do	24	50	nw.	Do	30	66	nw.	Do	18	52	nw.
Block Island, R. I.	4	50	nw.	El Paso, Tex	9	56	w.	Nantucket, Mass	12	54	s.	Do	25	70	nw.
Do	5	56	nw.	Do	13	50	w.	Do	15	60	s.	Do	26	55	nw.
Do	12	60	se.	Erie, Pa	11	60	se.	New York, N. Y	4	54	nw.	Do	27	67	nw.
Do	15	58	w.	Do	12	65	se.	Do	8	60	nw.	Do	28	50	nw.
Do	23	58	nw.	Galveston, Tex	11	56	nw.	Do	10	58	nw.	Do	29	60	nw.
Buffalo, N. Y	12	88	w.	Hatteras, N. C	12	52	sw.	Do	12	84	se.	Do	30	50	nw.
Do	13	72	sw.	Do	15	72	sw.	Do	13	54	w.	Port Huron, Mich.	12	52	sw.
Do	14	56	w.	Jacksonville, Fla	11	59	sw.	Do	15	73	nw.	Providence, R. I.	12	71	se.
Do	15	50	w.	Do	15	55	s.	Norfolk, Va	11	60	se.	Do	15	64	w.
Do	16	56	w.	Key West, Fla	3	50	nw.	Do	12	67	se.	Do	23	53	nw.
Do	28	52	w.	Lincoln, Nebr	23	50	nw.	Do	15	58	w.	Raleigh, N. C	15	52	w.
Do	29	56	w.	Mobile, Ala	11	57	sw.	North Head, Wash.	1	50	se.	Richmond, Va	12	60	sw.
Burlington, Vt	12	56	se.	Mount Tamalpais, Cal	3	60	nw.	Do	3	64	se.	Rochester, N. Y	11	60	se.
Cape May, N. J	12	52	s.	Do	4	54	nw.	Do	4	50	s.	Do	12	65	se.
Charlotte, N. C	11	60	sw.	Do	8	56	nw.	Do	13	60	se.	Do	28	54	se.
Do	12	56	sw.	Do	9	52	n.	Do	17	72	se.	San Antonio, Tex	10	52	n.
Cheyenne, Wyo	23	54	w.	Do	10	65	n.	Do	24	56	nw.	Sandy Hook, N. J.	12	66	s.
Do	24	61	w.	Do	12	64	nw.	Do	25	50	nw.	Do	15	64	w.
Cleveland, Ohio	12	52	sw.	Do	14	54	s.	Pensacola, Fla	6	58	w.	Savannah, Ga	11	56	sw.
Columbia, S. C	11	63	sw.	Do	18	60	nw.	Do	11	59	sw.	Tatoosh Island, Wash	1	56	s.
Del Rio, Tex	10	54	nw.	Do	20	54	n.	Do	14	58	s.	Do	3	50	s.
Detroit, Mich	12	66	sw.	Do	25	55	n.	Pittsburgh, Pa	12	58	w.	Toledo, Ohio	12	63	sw.
Do	13	54	sw.	Do	26	56	n.	Point Reyes Light, Cal	8	58	nw.	Trenton, N. J	8	50	w.
Duluth, Minn	12	60	nw.	Do	27	62	n.	Do	9	54	nw.	Do	12	64	s.
Eastport, Me	15	62	e.	Do	29	80	nw.	Do	11	53	nw.	Do	15	50	n. w.
Ellendale, N. Dak.	11	50	n.												
Do	23	58	nw.												

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by section, January, 1918.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	38.3	− 7.5	2 stations	79	27	St. Bernard	−17	13	7.32	+2.75	Mentone	11.03	Livingston	0.58
Arizona	40.0	− 1.9	Castle Hot Springs	86	1	Alpine	−15	22	1.90	+0.38	Carr's Ranch	7.85	Parker	0.23
Arkansas	27.3	−13.6	Pine Bluff	80	25	Calico Rock	−23	13	4.39	+0.44	Marked Tree	8.60	Texarkana	0.90
California	46.8	+ 1.0	Riverside	92	1	Madeline	− 2	21	1.14	−4.27	Crescent City	7.26	3 stations	0.00
Colorado	19.5	− 4.8	Canon City	75	4	2 stations	−33	21†	1.70	+0.51	Savage Basin	10.56	Two Buttes	0.03
Florida	53.9	− 5.2	Lakeland	89	28	Mount Pleasant	11	13	3.11	+0.27	Pensacola	5.53	Fort Lauderdale	0.48
Georgia	39.1	− 7.2	Brunswick	83	27†	Ramhurst	− 3	13	5.74	+1.80	Resaca	10.38	Savannah	0.95
Hawaii (Dec.)	70.9	+ 0.9	2 stations	91	1†	2 stations	49	2†	5.66	−3.00	Honomu	15.77	Kaanapali	1.18
Idaho	28.7	+ 4.4	Grace	68	3	2 stations	−31	31	2.55	+0.05	Burke	8.26	Challis	0.43
Illinois	12.6	−14.3	2 stations	56	25	2 stations	−23	12	2.44	−0.13	New Burnside	5.53	White Hall	0.73
Indiana	13.2	−15.7	Rome	50	25†	Marengo	−27	20	3.55	+2.36	Cambridge City	5.35	Goshen	1.15
Iowa	8.6	− 9.3	2 stations	53	1†	Washta	−35	31	1.02	−0.03	Le Claire	2.79	Northboro	0.26
Kansas	19.4	−10.4	3 stations	71	3†	Oberlin	−32	11	0.69	−0.03	Sedan	1.88	2 stations	0.08
Kentucky	20.6	−14.6	2 stations	62	28	Paducah	−20	12	5.09	+0.70	Middlesboro	10.28	Earlington	3.17
Louisiana	43.3	− 7.8	Schriever	81	27	Plain Dealing	− 3	12†	4.38	+0.26	Houma	8.80	De Ridder	0.86
Maryland-Delaware	21.5	−11.5	Denton, Md.	61	12	Oakland, Md.	−30	3	4.24	+0.88	Emmitsburg, Md.	6.11	Oakland, Md.	2.28
Michigan	8.8	−11.7	5 stations	36	6†	Humboldt	−44	31	1.55	−0.57	Marquette	4.57	Flint	0.49
Minnesota	0.5	− 8.0	2 stations	45	1†	Warroad	−49	26	0.63	−0.08	Zumbrota	1.63	2 stations	0.12
Mississippi	37.1	−10.3	Waynesboro	78	28	Hermando	−12	12	5.84	+1.30	Meridian	9.82	2 stations	2.85
Missouri	16.4	−14.0	Crocker	67	29	Dean (2)	−24	12	1.68	−0.71	Caruthersville	7.18	Lamonte	0.22
Montana	17.0	− 0.5	Augusta	66	2	2 stations	−51	31	1.37	+0.39	Hebgen Dam	4.24	2 stations	0.22
Nebraska														
Nevada	32.6	+ 2.7	Las Vegas	80	2†	Gold Creek	−25	31	0.70	−0.41	Clover Valley	2.87	3 stations	0.00
New England	13.2	− 7.9	Boston, Mass.	54	12	Pittsburg, N. H.	−44	28	2.89	−0.52	New London, Conn.	4.81	Pittsburg, N. H.	1.38
New Jersey	20.3	− 9.6	2 stations	56	12	Culvers Lake	−24	1	4.14	+0.35	Clayton	6.14	South Orange	2.78
New Mexico	29.8	− 5.5	Artesia	78	3	Vermejo Park	−30	11	1.09	+0.35	Bateman's Ranch	3.96	Orogrande	0.09
New York	12.6	−10.5	Medford	54	12	Chazy	−35	28	2.68	−0.27	Adams Center	6.03	Lockport	0.69
North Carolina	31.6	− 9.5	Wilmington	68	28	Highlands	−11	13	4.79	+1.08	Rock House	9.85	Beaufort	1.23
North Dakota	0.5	− 4.4	Berthold Agency	48	3	Langdon	−44	30	0.45	−0.09	Taylor	1.38	4 stations	T.
Ohio	14.9	−13.8	Marietta	49	6†	Gambier	−28	20	3.23	−0.45	Greenfield	5.72	Geneva	0.73
Oklahoma	26.5	−12.5	Waurika	75	26	Hooker	−20	11	1.08	−0.08	Sallisaw	3.32	Erick	0.01
Oregon	39.4	+ 4.3	Milton	71	1	Crescent	−21	31	4.48	−1.30	Gov't. Camp	24.95	Paisley (near)	0.28
Pennsylvania	16.2	−11.7	Philadelphia*	57	12	Brookville	−29	21	3.51	+0.33	Mt. Pocono	7.28	Warren	1.20
Porto Rico	72.7	− 0.5	San German	94	20	Aibonito	43	10	1.80	−1.75	Rio Grande (El Verde).	4.78	Guanico Centrale	0.00
South Carolina	37.3	−8.2	Yemassee	82	28	2 stations	− 2	1	4.45	+1.04	Clemson College	10.11	Charleston	1.13
South Dakota	7.2	− 8.4	Colome	64	3	Jefferson	−48	12	0.98	+0.25	Greenmont	4.50	Ipswich	0.14
Tennessee	26.5	−12.7	3 stations	67	27†	Huntingdon	−18	20	7.33	+2.81	Rugby	11.00	Bolivar	3.13
Texas	41.2	− 7.5	2 stations	96	26†	Romero	−15	11	0.82	−0.61	Winfield (near)	3.25	4 stations	0.00
Utah	27.2	+ 1.3	St. George	69	4	Black's Fork	−22	27	1.84	+0.24	Silver Lake	7.98	New Harmony	0.00
Virginia	25.2	−10.5	Ivor	65	12	Burkes Garden	−22	21	5.01	+1.76	Elk Knob	8.22	Rocky Mount	1.72
Washington	38.7	+ 5.5	Kennewick	71	18	Snyders Ranch	−14	24	11.55	+5.71	Cedar Lake	46.80	Hanford	0.50
West Virginia	20.7	−12.3	2 stations	55	6†	Marlinton	−27	21	4.25	+0.32	Pickens	9.22	Bayard	2.00
Wisconsin	4.0	−10.6	La Crosse	36	25	Winter	−45	31	1.89	+0.85	Waukesha	5.60	Grantsburg	0.41
Wyoming	16.0	− 3.9	Sussex	71	3	Soda Butte	−55	31	1.29	+0.29	Sand Lake	5.95	Green River	0.09

*Also at U. S. Navy Yard, Mare Island.

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, 75th meridian time, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.80

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the excessive rate ends.

In cases where no storm of sufficient intensity to entitle it to place in the full table has occurred, the greatest precipitation of any single storm has been given; also the greatest hourly fall during that storm.

The tipping-bucket mechanism is *dismounted* and removed when there is danger of snow or water freezing in the same. Table II records this condition by entering an asterisk (*).

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sealevel pressures have been computed at Washington by the method employed for reducing United States observations and described by Prof. F. H. Bigelow in this REVIEW, January, 1902, pages 13–16; the altitudes are those furnished us on January 1, 1916.

Chart I.—*Hydrographs* for several of the principal rivers of the United States.

Chart II.—*Tracks of centers* of HIGH areas; and

Chart III.—*Tracks of centers* of LOW areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading, or (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sealevel and standard gravity.

Chart IV.—*Temperature departures.* This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin R, Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908, have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—*Total precipitation.* The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—*Percentage of clear sky between sunrise and sunset.* The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—*Isobars and isotherms at sealevel, and prevailing wind directions.* The pressures have been reduced to sealevel and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sealevel plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction $t_0 - t$, or temperature on the sealevel plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sealevel temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—*Total snowfall.* This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

Chart IX.—Average values of pressure, air and surface water temperatures, and prevailing wind directions, and storm tracks over the North Atlantic Ocean *for the corresponding month of last year.*

Chart X.—Presents *annually* the tracks of *hurricanes of the year;* tracks of the same month are all in one color. This chart was first published in the issue for September, 1916.

Chart XI.—Presents *annually,* by means of a dot for each report, the *frequency of earthquakes* in the United States during the year. This chart was first published in the issue for December, 1915.

TABLE I.—*Climatological data for Weather Bureau Stations, January, 1918.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.							Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*									*0–10*	*In.*	*In.*
New England.							**17.0**	**−7.4**												**75**	**2.75**	**−0.80**											**5.9**		
Eastport	76	67	85	29.64	29.73	−0.27	15.4	−4.7	42	12	22	−11	28	9	32	14	11	81	2.88	−1.0	14	10,029	w.	62	e.	15	6	14	11	6.1	22.0	18.5
Greenville	1,070	6	....	28.55	29.77	.....	6.4	.....	34	13	16	−28	3	−3	36	....	....	....	2.49	.....	....	.....	.....	.....	.....	.....	11	6	14	....	25.0	33.0
Portland, Me.	103	82	117	29.69	29.82	−.23	15.0	−7.0	42	12	22	−9	2	8	27	12	6	70	3.48	−0.3	11	6,529	nw.	47	se.	12	14	5	12	5.2	16.7	16.0
Concord	288	70	79	29.50	29.84	−.21	13.3	−7.9	47	12	22	−14	3	4	33	....	....	....	1.65	−1.7	10	4,577	nw.	31	nw.	5	18	5	8	4.2	17.3	19.0
Burlington	404	11	48	29.40	29.88	−.17	9.0	−7.3	39	12	16	−24	28	2	34	....	....	....	1.73	−0.1	12	7,720	s.	56	se.	12	3	13	15	6.9	19.4	15.5
Northfield	876	12	60	28.87	29.86	−.19	6.1	−9.0	37	12	17	−33	2	−5	37	4	1	85	1.85	−0.6	9	4,920	s.	31	sw.	13	4	6	21	7.8	21.5	26.5
Boston	125	115	188	29.68	29.82	−.23	21.0	−6.0	54	12	28	−3	1	14	26	18	12	69	3.11	−0.7	11	8,955	w.	38	e.	12	11	8	12	5.5	13.8	4.6
Nantucket	12	14	90	29.80	29.80	−.24	24.0	−8.1	49	12	30	5	2	18	19	22	18	76	2.71	−0.7	11	13,327	w.	60	s.	15	5	14	12	6.4	15.0	4.0
Block Island	26	11	46	29.80	29.83	−.24	22.9	−8.5	51	12	28	2	2	18	24	21	17	78	2.80	−1.1	9	17,786	w.	60	se.	12	8	5	18	6.9	6.3	3.0
Narragansett Pier	....	9	....	....	....	....	20.1	−8.3	48	12	28	−5	2	12	28	....	....	....	3.32	.....	10	.....	w.	.....	.....	.....	13	7	11	....	9.8	3.0
Providence	160	215	251	29.65	29.84	−.22	20.3	−6.9	51	12	27	−4	2	13	24	17	13	76	3.11	−1.3	9	11,598	nw.	71	se.	12	8	13	10	5.4	7.0	1.9
Hartford	159	122	140	29.69	29.87	−.20	17.4	−8.1	51	12	25	−8	2	10	30	15	9	69	3.28	−0.6	11	5,802	nw.	32	sw.	13	8	14	9	4.9	13.2	9.0
New Haven	106	117	155	29.75	29.87	−.21	19.8	−7.5	50	12	27	−7	1	12	30	16	10	70	3.61	−0.3	12	7,786	n.	47	se.	12	9	12	10	5.4	10.3	3.4
Middle Atlanti ate							**22.7**	**−8.9**												**73**	**4.06**	**+0.7**											**5.9**		
Albany	97	102	115	29.79	29.90	+0.17	14.0	−8.5	47	12	22	−11	2	6	31	12	8	78	2.57	0.0	9	5,174	nw.	30	s.	12	13	6	12	5.3	13.0	11.0
Binghamton	871	10	69	28.91	29.88	−.20	14.0	−9.1	46	12	22	−14	2	6	43	....	....	....	2.32	+0.3	15	4,503	sw.	25	sw.	12	11	9	11	5.4	23.1	11.9
New York	314	414	454	29.54	29.90	−.20	21.6	−8.6	50	12	29	−5	1	14	34	18	11	66	3.41	−0.4	11	15,057	nw.	84	se.	12	8	10	13	6.2	13.6	4.6
Harrisburg	374	94	104	29.53	29.95	−.15	19.1	−9.6	42	12	26	−8	20	12	35	16	11	73	5.69	+2.9	15	5,503	w.	36	w.	12	10	7	14	5.7	31.0	22.0
Philadelphia	117	123	190	29.80	29.94	−.17	24.2	−7.6	57	12	30	2	4	18	39	22	16	73	4.06	+0.6	12	8,108	nw.	43	s.	12	9	5	17	6.5	27.0	13.2
Reading	325	81	98	29.57	29.95	.....	19.8	.....	54	12	26	1	4	13	45	17	13	77	4.64	+1.1	16	5,886	nw.	35	sw.	12	11	2	18	6.4	22.6	11.5
Scranton	805	111	119	29.02	29.92	−.17	17.4	−8.1	50	12	25	−5	3	10	41	15	11	78	4.71	+1.9	16	6,283	sw.	34	sw.	12	9	8	14	6.0	22.4	4.8
Atlantic City	52	37	48	29.86	29.92	−.19	24.4	−8.1	51	12	31	0	4	18	27	21	17	75	4.34	+0.9	13	6,795	nw.	36	s.	12	10	8	13	5.8	20.5	14.2
Cape May	18	13	49	.....	29.96	−.16	25.6	−8.5	50	12	31	3	4	20	26	....	....	....	3.54	+0.2	12	7,967	nw.	52	s.	12	11	9	11	....	18.5	13.3
Sandy Hook	22	10	57	29.88	29.90	.....	21.6	.....	51	12	28	1	4	16	33	19	14	72	3.54	.....	13	14,932	w.	66	s.	12	9	10	12	5.7	9.4	2.8
Trenton	190	159	183	29.70	29.91	.....	20.4	.....	54	12	27	−1	1	14	39	18	14	78	3.00	−0.2	12	10,389	w.	64	s.	12	9	5	17	6.0	19.3	8.6
Baltimore	123	100	113	29.82	29.96	−.16	24.2	−9.2	52	12	30	4	4	18	38	21	14	65	5.00	+1.8	13	5,687	sw.	46	se.	12	8	8	15	6.4	21.9	14.8
Washington	112	62	85	29.87	29.95	−.18	23.7	−9.2	50	12	30	1	1	18	34	20	14	69	4.29	+0.9	14	5,425	nw.	38	w.	15	9	7	15	6.2	22.6	11.6
Lynchburg	681	153	188	29.17	29.94	−.19	27.0	−8.8	50	25	35	0	21	19	31	23	17	68	4.42	+0.7	13	5,142	w.	30	nw.	15	10	10	11	5.9	19.6	7.9
Norfolk	91	170	205	29.85	29.95	−.18	31.6	−8.8	63	12	39	5	4	24	39	28	22	72	2.77	−0.6	13	9,978	w.	67	se.	12	11	8	12	5.5	9.1	0.0
Richmond	144	11	52	29.80	29.96	−.17	28.0	−10.0	60	12	36	−1	4	20	46	24	19	73	5.81	+2.8	14	6,538	sw.	60	sw.	12	9	12	10	5.9	14.4	2.6
Wytheville	2,293	49	55	27.46	29.97	−.17	22.6	−10.4	49	27	31	−8	21	14	38	20	17	84	4.32	0.0	14	6,735	w.	48	w.	15	11	5	15	6.1	19.2	6.0
South Atlantic States.							**38.6**	**−6.6**												**76**	**2.76**	**−1.0**											**5.2**		
Asheville	2,255	70	84	27.51	29.97	−0.18	28.8	−6.6	58	28	37	−2	13	20	31	25	22	80	4.56	−0.1	16	7,435	nw.	35	n.	12	8	8	15	6.3	11.1	0.0
Charlotte	773	153	161	29.10	29.96	−.19	32.4	−8.0	56	25	41	6	13	24	35	29	24	77	3.82	−0.5	14	8,019	sw.	60	sw.	11	13	5	13	5.4	1.5	0.0
Hatteras	11	12	50	29.93	29.94	−.20	37.6	−8.2	62	12	45	11	4	30	32	34	31	85	1.78	−3.2	10	12,487	w.	72	sw.	15	8	10	13	6.4	2.4	0.0
Manteo	12	4	46	.....	.....	.....	34.4	.....	58	12	42	9	4	26	....	....	....	....	2.20	−2.4	10	.....	n.	.....	.....	.....	14	1	16	....	.....	.....
Raleigh	376	103	110	29.54	29.96	−.17	32.4	−8.0	65	11	41	6	4	24	47	28	24	76	4.80	+1.2	14	5,955	ne.	52	w.	15	10	9	12	5.3	5.7	0.0
Wilmington	78	81	91	29.89	29.98	−.16	39.3	−6.3	68	28	49	11	4	30	36	34	29	73	2.17	−1.3	12	6,249	w.	47	s.	11	15	4	12	4.8	0.1	0.0
Charleston	48	11	92	29.94	29.99	−.16	42.4	−6.9	73	27	51	18	13	34	31	37	32	75	1.13	−2.3	11	8,087	w.	47	s.	11	18	4	9	3.8	0.5	0.0
Columbia, S. C.	351	41	57	29.59	29.98	−.17	38.2	−6.9	71	27	48	6	1	29	36	33	27	72	2.16	−1.1	11	6,817	sw.	63	sw.	11	14	3	14	5.5	1.0	0.0
Greenville, S. C.	1,039	113	122	28.81	29.94	.....	32.8	.....	60	28	40	4	13	25	28	29	25	80	7.42	.....	15	7,686	sw.	45	sw.	12	10	7	14	5.7	2.5	0.0
Augusta	180	62	77	29.78	29.98	−.18	40.0	−5.9	74	27	50	12	1	30	37	35	32	79	3.42	−0.7	13	5,382	w.	48	w.	11	11	6	14	5.7	1.0	0.0
Savannah	65	150	194	29.93	30.00	−.15	44.8	−5.1	77	28	55	18	13	35	31	38	34	73	0.95	−2.2	9	9,084	w.	56	sw.	11	15	7	9	4.7	0.5	0.0
Jacksonville	43	200	245	29.97	30.02	−.13	50.0	−3.9	79	28	60	21	1	40	29	44	39	74	2.78	−0.3	10	10,200	sw.	59	sw.	11	16	7	8	4.1	0.0	0.0
Florida Peninsula.							**61.8**	**−2.7**												**78**	**1.63**	**−1.1**											**3.8**		
Key West	22	10	64	30.00	30.02	−0.08	66.4	−2.4	80	31	72	46	4	60	23	61	59	81	1.05	−0.9	5	8,088	e.	50	nw.	3	17	12	2	3.3	0.0	0.0
Miami	25	71	79	30.02	30.05	.....	62.8	−4.5	81	15	71	32	4	54	49	57	54	77	0.85	−2.6	8	6,044	nw.	33	nw.	3	17	11	3	3.4	0.0	0.0
Sand Key	23	39	72	29.98	30.01	−.09	67.0	.....	77	11	71	50	4	63	16	63	60	77	0.94	.....	6	12,184	ne.	46	nw.	3	17	9	5	3.7	0.0	0.0
Tampa	35	79	96	30.00	30.04	−.08	56.2	−1.2	80	31	66	31	4	47	31	50	47	78	3.00	+0.2	11	4,986	nw.	46	sw.	11	10	13	8	5.0	0.0	0.0
East Gulf States.							**41.3**	**−6.1**												**69**	**6.77**	**+1.3**											**3.6**		
Atlanta	1,174	190	216	28.70	29.97	−0.18	34.8	−7.4	68	27	42	4	13	28	26	32	28	77	9.12	+3.8	13	9,153	w.	60	sw.	11	8	5	18	6.8	2.9	0.0
Macon	370	78	87	29.59	29.99	−.17	40.0	−5.6	74	28	50	10	13	30	42	36	31	75	5.40	+0.2	10	5,036	s.	33	sw.	11	11	4	16	5.9	T.	0.0
Thomasville	273	49	58	29.70	30.01	−.15	46.0	−5.0	77	29	57	15	13	35	36	40	36	74	3.73	−0.4	10	4,238	sw.	36	sw.	11	11	9	11	5.4	0.0	0.0
Pensacola	56	149	185	29.94	30.00	−.14	47.4	−4.9	68	27	56	18	12	39	46	44	40	78	5.53	+1.5	9	11,615	n.	59	sw.	11	14	5	12	5.2	0.0	0.0
Anniston	741	9	57	29.22	30.00	−.16	36.2	−6.0	70	27	45	3	12	28	32	....	....	....	8.59	+3.3	13	5,529	w.	37	nw.	11	9	10	12	5.8	1.3	0.0
Birmingham	700	11	48	29.22	30.01	−.15	36.6	−8.8	73	27	45	1	12	28	36	32	28	73	8.94	+3.6	14	6,282	w.	42	se.	14	10	5	16	6.2	1.3	0.0
Mobile	57	125	161	29.94	30.00	−.15	45.7	−4.1	75	28	55	17	12	36	45	41	38	78	3.87	−1.0	10	9,081	nw.	57	sw.	11	11	11	9	4.8	T.	0.0
Montgomery	223	100	112	29.75	30.01	−.15	41.6	−6.1	77	27	51	12	12	32	51	37	32	73	8.34	+3.2	11	5,999	se.	41	w.	11	10	10	11	5.6	0.1	0.0
Corinth	469	6	....	.....	.....	.....	28.0	.....	64	25	39	−8	13	17	48	....	....	....	5.20	.....	12	.....	n.	.....	.....	.....	8	9	14	....	14.0	0.0
Jackson	304	5	....	.....	.....	.....	38.8	.....	77	27	49	4	13	29	43	....	....	....	6.67	.....	13	.....	nw.	.....	.....	.....	13	7	11	....	0.5	0.0
Meridian	375	85	93	29.59	30.00	−.16	39.2	−5.8	73	27	49	7	12	29	40	35	31	76	9.82	+4.3	14	5,664	w.	47	sw.	14	11	9	11	5.5	1.1	0.0
Vicksburg	247	65	74	29.74	30.03	−.12	39.0	−8.0	73	27	48	4	12	30	34	34	30	74	6.72	+1.0	11	6,689	nw.	36	sw.	5	13	6	12	5.3	1.4	0.0
New Orleans	51	76	84	29.95	30.00	−.13	48.1	−4.9	79	28	58	17	12	39	45	44	40	79	4.43	−0.2	12	6,420	nw.	30	s.	14	12	8	11	4.9	T.	0.0
West Gulf States.							**38.7**	**−7.4**												**71**	**1.72**	**−1.2**											**4.3**		
Shreveport	249	77	93	29.74	30.02	−0.12	38.2	−8.0	73	26	48	2	12	28	37	33	27	70	2.07	−2.4	5	6,849	se.	32	se.	14	16	3	12	4.9	3.0	0.0
Bentonville	1,303	11	44	28.58	30.01	−.13	21.5	−12.6	62	26	32	−15	12	11	40	....	....	....	2.68	0.0	10	4,459	nw.	19	nw.	2	13	7	11	5.5	21.0	0.5
Fort Smith	457	79	94	29.52	30.03	−.11	25.8	−12.5	65	26	35	−11	12	17	32	22	17	72	2.86	+0.4	8	6,833	e.	32	nw.	11	10	6	15	5.8	13.6	0.0
Little Rock	357	139	147	29.63	30.03	−.12	28.6	−12.0	62	26	36	−8	12	21	31	26	20	73	5.51	+0.7	13	7,226	w.	37	nw.	11	12	4	15	5.7	19.4	1.8
Brownsville	57	4	26	.....	.....	.....	58.0	.....	85	5	72	25	11	44	45	....	....	....	0.08	.....	2	.....	n.	.....	.....	.....	....	....	....	....	....	....
Corpus Christi	20	69	77	30.00	30.02	−.08	50.6	−2.9	83	26	61	20	12	40	43	45	40	72	0.07	−2.2	3	9,251	se.	46	nw.	10	12	11	8	4.7	0.4	0.0
Dallas	512	109	117	29.46	30.03	.....	35.6	.....	76	25	47	3	12	24	40	....	....	....	1.84	.....	5	7,603	nw.	35	nw.	11	19	5	7	3.8	9.0	0.0
Fort Worth	670	106	114	29.27	30.01	−.11	36.8	−7.5	77	26	48	4	11	25	40	32	27	72	1.36	+0.4	6	9,230	nw.	38	nw.	10	20	5	6	3.4	6.2	T.
Galveston	54	106	114	29.96	30.02	−.11	47.8	−4.9	70	5	56	16	11	40	36	43	39	76	0.54	−3.1	7	10,004	n.	56	nw.	11	13	8	10	4.7	0.5	0.0
Houston	138	111	121	29.86	30.02	.....	47.2	−5.7	77	25	58	11	12	36	35	....	....	....	0.96	.....	9	7,311	nw.	32	nw.	11	18	5	8	3.7	0.2	0.0
Palestine	510	64	72	29.46	30.01	−.11	40.6	−5.9	76	25	52	3	12	29	38	35	32	79	1.37	−2.5	6	6,890	nw.	30	sw.	8	15	8	8	4.0	5.5	0.0
Port Arthur, Tex	34	58	66	29.95	29.99	.....	45.4	.....	70	14	55	12	12	36	41	41	37	80	0.73	.....	9	8,337	s.	42	nw.	11	14	7	10	4.5	0.5	0.0
San Antonio	701	119	132	29.26	30.00	−.10	47.0	−4.1	84	25	60	12	12	34	56	38	28	54	0.10	−1.6	1	7,023	n.	52	n.	10	20	7	4	3.1	0.4	0.0
Taylor	582	55	63	29.41	30.04	−.07	41.8	−5.7	85	25	55	5	12	29	44	....	....	....	0.59	−2.2	6	8,344	n.	39	n.	10	20	4	7	3.1	2.0	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, January, 1918*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Ohio Valley and Tennessee.							**21.1**	**−12.1**											**82**	**4.35**	**+0.7**									**6.7**		
Chattanooga	762	189	213	29.15	29.99	−0.17	32.0	−8.6	67	28	39	−1	12	25	34	29	24	73	7.37	+1.8	20	6,320	w.	44	w.	11	8	5	18	6.7	9.9	0.0
Knoxville	996	102	111	28.87	29.96	− .19	29.2	−8.3	65	28	36	−2	12	22	33	28	25	84	6.62	+1.6	17	5,741	sw.	38	sw.	15	4	10	17	6.9	11.9	0.0
Memphis	399	76	97	29.60	30.04	− .12	27.6	−12.7	62	5	35	−8	12	20	31	25	22	80	5.02	−0.2	13	7,550	n.	48	nw.	14	13	3	15	5.6	13.9	0.0
Nashville	546	168	191	29.40	30.00	− .16	26.4	−11.6	56	26	35	−10	12	18	39	24	20	79	7.43	+2.6	13	7,613	nw.	43	nw.	11	7	11	13	6.5	18.5	T.
Lexington	989	193	230	28.86	29.99	− .14	19.8	−13.2	47	26	27	−14	12	12	36				4.46	+0.6	21	10,901	sw.	42	sw.	12	7	9	15	6.2	21.7	3.0
Louisville	525	219	255	29.38	30.00	− .14	19.6	−14.7	47	6	27	−15	12	12	36	18	15	80	3.49	−0.4	14	9,796	sw.	49	sw.	12	8	8	15	6.2	24.6	7.6
Evansville	431	139	175	29.49	29.98	− .16	19.4	−12.9	49	26	28	−16	12	11	33	17	14	82	5.00	+1.3	16	9,040	sw.	43	sw.	11	4	16	11	6.2	41.0	9.5
Indianapolis	822	194	230	29.02	29.95	− .17	14.6	−15.7	43	6	22	−19	12	7	33	13	9	79	2.89	+0.1	12	10,052	w.	46	w.	11	7	12	12	6.2	22.0	5.0
Terre Haute	575	96	129	29.31	29.96		14.8		43	6	23	−18	12	7	33	13	11	85	2.63		11	7,913	sw.	37	nw.	12	5	16	10	6.4	20.1	7.2
Cincinnati	628	11	51	29.25	29.96	− .16	16.3	−14.0	45	6	24	−16	12	8	32	15	13	88	4.30	+0.9	16	7,327	sw.	36	sw.	12	6	11	14	6.7	20.2	7.5
Columbus	824	173	222	29.03	29.95	− .17	15.8	−12.8	42	6	23	−13	12	8	26	14	10	78	3.51	+0.6	17	9,930	sw.	48	w.	12	6	10	15	6.5	25.4	7.0
Dayton	899	181	216	28.97	29.92		15.0	−13.9	43	6	23	−16	12	7	29	14	11	84	3.46	+0.4	18	9,185	sw.	45	w.	12	8	12	11	6.3	24.4	13.0
Pittsburgh	842	353	410	29.00	29.94	− .17	18.6	−12.1	41	11	26	−5	12	11	45	16	13	80	2.82	0.0	18	9,878	sw.	58	w.	12	4	6	21	7.7	19.1	7.2
Elkins	1,940	50	67	27.79	29.96	− .16	20.7	−8.3	50	26	30	−15	21	12	46	18	16	86	5.11	+1.8	25	5,140	w.	38	sw.	15	2	3	26	8.5	19.6	2.6
Parkersburg	638	77	84	29.29	29.97	− .15	20.3	−11.0	49	6	29	−10	21	12	45	18	15	83	2.24	−1.0	20	3,428	sw.	26	sw.	12	6	5	20	7.5	17.2	2.1
Lower Lakes Region.							**13.4**	**−10.4**											**83**	**2.88**	**+0.2**									**6.8**		
Buffalo	767	247	280	29.02	29.89	−0.18	14.1	−10.6	40	12	21	−6	13	8	46	12	10	86	5.64	+2.3	22	16,759	w.	88	w.	12	6	9	16	6.7	40.8	24.0
Canton	448	10	61	29.36	29.88		7.5	−8.8	39	12	15	−30	28	0	36				2.37	−0.8	17	8,588	w.	48	w.	12	11	6	14	5.8	22.3	16.1
Oswego	335	76	91	29.51	29.89	− .18	14.0	−9.9	33	12	20	−8	2	8	32	14	11	86	1.69	−1.5	13	10,145	nw.	41	sw.	13	2	10	19	7.6	28.3	18.5
Rochester	523	97	113	29.31	29.91	− .16	14.8	−9.2	40	12	21	−2	13	8	41	13	9	80	2.25	−0.9	19	8,578	sw.	43	w.	12	9	4	18	6.8	17.2	11.0
Syracuse	597	97	113	29.23	29.91	− .16	14.2	−8.8	42	12	21	−9	2	8	39	12	10	86	3.60	+1.5	17	9,149	w.	39	w.	10	3	13	15	7.1	31.0	11.5
Erie	714	130	166	29.10	29.91	− .17	15.0	−8.5	37	6	22	−8	12	8	44	13	10	80	1.75	−1.3	15	12,558	sw.	65	se.	12	1	13	17	7.4	13.6	6.5
Cleveland	762	190	201	29.07	29.93	− .16	15.0	−11.2	40	6	22	−9	12	8	44	13	10	80	2.60	+0.2	19	11,424	sw.	52	sw.	12	3	11	17	7.5	24.8	9.0
Sandusky	629	62	103	29.21	29.93	− .16	14.6	−11.7	40	6	21	−12	12	8	45	12	9	80	2.77	+0.7	17	11,727	sw.	48	sw.	12	5	11	15	6.8	23.0	11.3
Toledo	678	208	243	29.22	29.94	− .15	13.7	−11.9	38	25	21	−15	12	7	43	12	9	85	3.65	+1.7	15	13,339	sw.	63	sw.	12	9	6	16	6.3	26.2	11.8
Fort Wayne	856	113	124	28.97	29.94		11.4	−12.9	37	25	19	−24	12	4	28	10	8	85	2.19		17	9,017	sw.	44	s.	12	6	13	12	5.9	25.4	13.5
Detroit	730	218	245	29.08	29.91	− .17	13.2	−11.1	36	6	20	−16	12	6	42	11	9	84	2.53	+0.6	13	11,617	sw.	66	sw.	12	8	10	13	6.4	18.6	9.0
Upper Lakes Region.							**8.5**	**−9.8**											**85**	**2.56**	**+0.6**									**6.9**		
Alpena	609	13	97	29.18	29.88	−0.16	8.2	−10.5	25	11	16	−17	31	1	31	8	5	86	1.41	−0.8	13	8,598	nw.	35	e.	28	3	15	13	6.5	21.5	15.0
Escanaba	612	54	60	29.21	29.91	− .14	6.7	−7.8	25	5	13	−19	31	1	27	6	4	91	1.12	−.04	15	7,183	nw.	36	n.	7	11	8	12	5.9	12.8	11.0
Grand Haven	637	54	97	29.18	29.90	− .17	13.2	−11.3	30	25	19	−11	27	7	25	12	8	77	2.99	+0.2	19	10,261	w.	48	s.	12	5	6	20	7.6	36.3	4.4
Grand Rapids	707	70	87	29.10	29.91	− .15	12.5	−11.3	30	25	18	−14	19	7	35	11	8	83	3.24	+0.5	20	5,548	w.	27	ne.	6	3	11	17	7.3	45.0	18.0
Houghton	684	62	99	29.15	29.91	− .14	6.6	−7.9	26	6	13	−28	31	0	29				2.65	+0.6	21	7,328	w.	35	nw.	12	4	7	20	8.0	27.7	35.0
Lansing	878	11	62	28.92	29.90		10.2	−11.8	32	25	18	−17	12	2	38	8	5	86	2.08	0.0	15	5,781	sw.	32	sw.	12	6	9	16	6.9	22.7	12.5
Ludington	637	60	66	29.17	29.89		12.4		29	25	18	−11	31	7	21	12	10	88	3.21		20	9,235	w.	38	nw.	12	2	6	23	8.3	43.5	21.5
Marquette	734	77	111	29.09	29.93	− .11	8.8	−7.1	24	5	15	−19	31	3	20	7	4	88	4.77	+2.7	20	8,859	w.	38	nw.	12	4	11	16	7.4	50.1	30.0
Port Huron	638	70	120	29.17	29.90	− .16	10.9	−10.9	36	6	18	−15	12	4	44	9	7	86	1.74	−0.2	14	9,449	sw.	52	sw.	12	8	11	12	5.9	19.6	11.8
Saginaw	641	48	82	29.16	29.90		10.4		30	25	18	−15	12	3	40	9	8	92	2.18	−0.1	14	8,305	w.	43	s.	12	3	9	19	7.8	21.7	22.0
Sault Ste. Marie	614	11	61	29.16	29.90	− .13	3.2	−10.1	20	5	11	−22	31	−5	33	3	−1	83	0.99	−1.2	17	5,952	e.	41	nw.	25	7	4	20	7.3	12.1	17.4
Chicago	823	140	310	29.01	29.95	− .15	13.3	−10.4	35	25	20	−14	12	7	26	12	7	76	4.12	+2.1	15	10,699	w.	44	ne.	6	9	7	15	6.1	42.5	23.8
Green Bay	617	109	144	29.22	29.92	− .14	5.8	−8.8	28	5	13	−17	31	−2	25	5	0	76	2.22	+0.5	13	9,518	sw.	42	n.	6	8	6	17	6.8	25.1	16.3
Milwaukee	681	119	133	29.14	29.91	− .17	10.0	−9.8	34	25	17	−11	18	4	25	9	6	84	5.38	+3.4	14	9,464	w.	44	n.	6	12	8	11	5.2	52.6	19.8
Duluth	1,133	11	47	28.68	29.98	− .11	0.8	−9.6	24	5	9	−28	31	−7	35	−1	−2	95	0.94	0.0	10	10,506	nw.	60	nw.	12	8	9	14	6.1	12.1	10.4
North Dakota.							**−1.1**	**−5.2**											**88**	**0.56**	**0.0**									**6.4**		
Moorhead	940	8	57	29.02	30.11	−0.03	−1.4	−4.1	34	24	7	−30	30	−10	32	−2	−6	82	0.61	−0.1	12	7,088	nw.	30	n.	24	12	5	14	5.5	6.1	8.5
Bismarck	1,674	8	57	28.25	30.16	+ .03	1.4	−5.3	43	1	9	−29	30	−7	33	0	−1	90	0.67	+0.1	10	8,984	nw.	47	nw.	23	7	6	18	6.9	10.3	10.0
Devils Lake	1,482	11	44	28.39	30.09	− .03	−4.6	−4.9	37	1	4	−36	30	−14	36	−5	−7	92	0.24	−0.4	9	9,057	nw.	36	nw.	1	8	5	18	6.5	2.8	4.0
Ellendale	1,457	10	56	28.44	30.09		1.4		43	1	9	−28	30	−6	31	0	−1	90	0.42		9	12,507	nw.	58	nw.	23	9	8	14	6.2	4.2	1.0
Grand Forks	835	12	89				−3.6		31	24	6	−35	30	−13	34				0.50		8		nw.	36	nw.	24	16	4	11		5.0	5.5
Williston	1,872	41	48	28.02	30.14	+ .03	0.2	−6.3	40	1	9	−33	13	−8	46	0	−2	88	0.75	+0.2	10	6,525	w.	48	nw.	23	4	13	14	6.6	5.9	2.7
Upper Mississippi Valley.							**10.7**	**−10.8**											**83**	**1.38**	**−0.3**									**5.3**		
Minneapolis	918	10	208	28.95	29.98		4.0		36	24	12	−22	31	−4	37				0.38	−0.3	13	9,375	nw.	37	nw.	24	9	9	13	5.9	5.3	5.0
St. Paul	837	201	236	29.05	30.01	−0.10	3.7	−7.9	35	24	11	−25	31	−4	41				0.51	−0.4	13	9,836	nw.	40	nw.	12	9	11	11	5.5	8.1	4.0
La Crosse	714	11	48	29.17	30.00	− .11	5.4	−9.8	36	25	14	−23	31	−4	34	1.3			1.33	+0.2	12	4,159	nw.	22	nw.	25	11	7	13	5.6	14.8	10.0
Madison	974	70	78	28.84	29.96	− .14	5.6	−10.9	34	25	13	−18	31	−2	28	5	2	85	2.09	+0.5	15	8,731	nw.	46	n.	6	9	8	14	6.1	24.5	16.8
Wausau	1,247	4	....	28.51	29.92		4.0		25	5	12	−24	31	−4	33				0.86		10		nw.				13	5	13	5.4	9.6	7.9
Charles City	1,015	10	49	28.87	30.01	− .13	5.0	−6.4	37	1	15	−27	31	−5	37	3	1	88	0.85	−0.1	11	5,959	nw.	24	nw.	12	7	12	12	6.2	14.2	6.5
Davenport	606	71	79	29.30	30.00	− .12	10.0	−10.8	38	23	18	−18	12	2	41	9	6	85	1.56	0.0	13	6,837	w.	29	n.	6	12	5	14	5.8	16.8	9.4
Des Moines	861	84	97	29.05	30.01	− .13	11.8	−8.6	44	4	21	−20	31	3	38	11	7	78	0.78	−0.4	7	6,351	nw.	26	n.	1	6	14	11	6.0	8.3	4.2
Dubuque	698	81	96	29.20	30.00	− .12	8.2	−10.1	37	25	17	−16	31	0	43	7	4	86	1.83	+0.3	15	5,828	nw.	31	n.	6	13	5	13	5.5	17.5	12.4
Keokuk	614	64	78	29.30	30.02	− .12	12.4	−11.3	41	4	21	−21	11	4	33	11	8	82	0.70	−1.0	6	6,702	nw.	35	nw.	12	10	13	8	5.1	8.0	4.5
Cairo	356	87	93	29.59	29.99	− .17	21.0	−13.8	53	25	29	−16	12	13	27	19	14	74	3.47	−0.4	12	7,514	n.	43	n.	2	9	7	15	6.0	24.2	4.4
Peoria	609	11	45	29.29	29.99	− .13	10.4	−12.7	36	25	19	−21	12	2	40	9	7	89	1.58	−0.6	11	6,463	w.	32	n.	6	12	5	14	5.6	16.9	9.0
Springfield, Ill	644	10	91	29.26	29.97	− .16	13.6	−12.7	39	25	21	−20	12	6	32	12	8	81	1.88	−0.4	11	7,263	w.	30	nw.	11	7	9	15	6.2	19.2	12.0
Hannibal	534	74	109	29.40	30.00	− .13	13.6	−13.1	42	1	22	−20	12	5	37				0.98	−1.2	8	7,659	sw.	40	sw.	12	7	7	17	6.3	15.8	3.8
St. Louis	567	265	303	29.36	29.99	− .15	18.8	−12.2	45	25	26	−17	12	12	29	16	13	79	1.31	−1.0	11	10,335	nw.	46	w.	11	6	13	12	6.8	11.7	0.7
Missouri Valley.							**12.6**	**−8.5**											**83**	**0.95**	**0.0**									**5.5**		
Columbia, Mo	781	11	84	29.14	30.02	−0.11	15.4	−11.8	44	1	24	−19	12	7	35				1.00	−1.2	7	6,905	sw.	34	nw.	2	7	9	15	6.4	11.6	1.0
Kansas City	963	161	181	28.95	30.03	− .12	17.4	−8.8	51	24	26	−16	11	9	35	15	10	73	0.94	−0.2	7	9,688	n.	44	nw.	2	12	10	9	5.1	10.3	2.6
St. Joseph	967	11	49	28.93	30.04		15.6		52	24	24	−19	12	7	36	13	10	81	0.67		7	7,305	nw.	36	nw.	1	9	9	13	5.5	6.4	3.0
Springfield, Mo	1,324	98	104	28.55	30.02	− .12	18.4	−12.9	55	26	27	−19	12	10	38	16	14	85	1.96	−0.7	11	8,043	w.	32	n.	2	19	3	9	4.0	23.0	0.5
Iola	984	11	50	28.94	30.05	− .09	17.6	−10.0	55	1	27	−18	12	8	40				0.90	−0.1	7	5,827	n.	30	n.	2	13	5	13	5.3	7.8	3.1
Topeka	983	85	101				17.2	−8.4	53	24	27	−16	12	8	33				0.51	−0.4	5	8,118	nw.	37	n.	2	13	6	12	5.0	9.4	2.3
Drexel	1,299	10	54	28.59	30.06		10.6		52	1	21	−24	11	0	32	8	6	88	0.49		6	8,413	nw.	36	nw.	23	10	8	13	5.8	9.2	5.0
Lincoln	1,189	11	84	28.72	30.06	− .09	12.7	−9.5	56	4	23	−23	11	2	40	11	8	83	0.58	0.0	9	8,921	nw.	50	nw.	23	9	14	8	5.0	7.4	3.3
Omaha	1,105	115	122	28.81	30.07	− .08	12.7	−7.8	51	1	21	−22	11	4	30	11	6	75	0.65	0.0	7	7,998	nw.	42	n.	2	11	10	10	5.2	7.0	3.0
Valentine	2,598	47	54	27.24	30.12	.00	10.0	−8.2	60	3	20	−32	11	0	42	9	8	92	0.71	+0.2	9	7,817	nw.	38	nw.	23	8	9	14	6.2	7.4	4.8
Sioux City	1,135	94	164	28.79	30.08	− .07	8.2	−7.4	48	1	17	−26	11	−1	38	7	4	85	1.37	+0.8	10	10,119	nw.	46	nw.	22	8	8	15	5.9	14.6	6.0
Huron	1,306	59	74	28.64	30.13	− .03	4.8	−4.7	50	1	14	−28	30	−4	31	3	−2	87	0.71	+0.2	13	9,441	nw.	48	nw.	23	10	11	10	5.2	6.8	2.8
Pierre	1,572	70	75	28.38	30.15	+ .02	8.0	−5.9	56	3	16	−28	30	0	41	7	3	77	1.08	+0.6	13	7,742	nw.	44	nw.	23	9	6	16	6.4	16.1	4.6
Yankton	1,233	49	57	28.68	30.08	− .08	8.6	−6.9	50	1	18	−26	11	0	39				1.02	+0.5	11	7,285	nw.	32	nw.	23	6	10	15	6.3	11.7	8.0

TABLE I.—*Climatological data for Weather Bureau Stations, January, 1918*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.		°F.	°F.	%	*In.*	*In.*		*Miles*							*0–10*	*In.*	*In.*
Northern Slope.							**16.1**	**−2.9**											**78**	**1.18**	**+0.3**									**6.5**		
Billings	3,140	5	.....	.....	.....	.....	16.6	.....	53	2	26	−38	31	8	39	.....	.....	.....	.....	2.00	.....	12	.....	.....	.....	.....	.....	6	17	8	.....	23.0	8.0
Havre	2,505	11	44	27.36	30.15	+0.05	10.8	−2.7	53	2	19	−39	31	3	52	9	7	86	1.19	+0.5	14	6,031	sw.	39	w.	22	8	8	15	6.5	11.9	7.3
Helena	4,110	87	112	25.75	30.10	− .05	21.0	+1.0	59	1	29	−29	31	13	32	18	14	75	1.07	+0.2	16	5,568	sw.	42	sw.	4	3	12	16	7.4	13.4	5.8
Kalispell	2,962	11	34	26.92	30.10	− .02	21.8	+2.2	45	4	28	−26	31	15	39	21	19	89	1.82	+0.2	19	3,162	nw.	34	ne.	29	3	6	22	7.9	16.4	9.6
Miles City	2,371	48	55	27.50	30.19	+ .07	10.8	−3.7	49	2	19	−34	31	2	32	9	7	84	1.32	+0.7	16	4,519	nw.	43	s.	22	8	17	6	5.3	12.4	8.8
Rapid City	3,259	50	58	26.54	30.16	+ .06	13.2	−8.3	60	1	24	−28	30	3	42	11	6	73	1.25	+0.8	13	6,807	n.	40	nw.	23	7	11	13	6.3	13.0	7.0
Cheyenne	6,088	84	101	23.81	30.00	− .05	19.8	−5.8	59	2	30	−16	31	10	46	16	10	67	0.47	+0.1	10	12,314	nw.	61	w.	24	5	17	9	6.2	6.6	0.1
Lander	5,372	60	68	24.52	30.10	− .02	16.8	−0.6	64	1	30	−27	31	3	48	12	6	66	1.07	+0.6	6	2,956	sw.	36	w.	29	9	16	6	5.5	10.2	1.0
Sheridan	3,790	10	47	26.05	30.12	.....	15.6	.....	58	2	27	−32	31	4	53	13	10	81	2.21	.....	19	4,103	nw.	38	nw.	8	4	9	18	7.3	23.6	10.4
Yellowstone Park	6,200	11	48	23.75	30.10	− .04	16.2	−1.4	47	1	25	−32	31	7	35	14	11	78	1.98	−0.3	22	4,387	s.	32	sw.	3	6	8	16	6.8	20.8	12.7
North Platte	2,821	11	51	27.03	30.11	− .01	14.8	−6.6	66	3	26	−25	11	3	45	12	8	78	0.54	+0.1	11	6,175	w.	29	n.	10	8	11	12	5.7	5.3	2.6
Middle Slope.							**21.4**	**−7.8**											**74**	**0.78**	**+0.1**									**4.8**		
Denver	5,292	106	113	24.58	30.01	−0.04	24.6	−4.5	65	3	36	−11	31	13	45	19	12	65	0.59	+0.2	9	5,920	se.	38	nw.	23	10	13	8	5.5	8.1	1.3
Pueblo	4,685	80	86	25.17	30.02	− .03	22.8	−6.3	71	1	37	−15	11	8	45	19	13	69	0.61	+0.3	8	4,284	nw.	37	nw.	29	11	7	13	5.5	7.5	0.4
Concordia	1,392	50	58	28.54	30.09	− .05	15.3	−9.1	60	1	26	−20	11	4	40	13	11	86	0.85	+0.1	5	6,739	nw.	31	nw.	12	9	10	12	5.5	8.7	2.0
Dodge City	2,509	11	51	27.35	30.07	− .06	21.1	−6.2	67	4	33	−19	11	9	41	16	10	67	0.80	+0.3	6	7,926	nw.	38	n.	30	15	9	7	4.0	9.3	T.
Wichita	1,358	139	158	28.54	30.05	− .08	19.4	−10.3	64	1	29	−14	11	10	40	17	14	82	0.80	+0.1	5	9,731	n.	39	nw.	6	17	6	8	4.2	8.7	0.5
Altus	1,410	5	.....	.....	.....	.....	31.2	.....	68	1	44	−3	11	18	46	.....	.....	.....	0.61	.....	4	.....	n.	.....	.....	.....	20	2	9	.....	4.0	T.
Muskogee	652	4	.....	.....	.....	.....	23.7	.....	68	26	36	−11	12	11	50	.....	.....	.....	2.25	.....	9	.....	n.	.....	.....	.....	9	6	16	.....	10.6	0.0
Oklahoma	1,214	10	47	28.71	30.05	− .06	25.0	−9.7	63	26	35	−7	11	15	45	21	17	78	0.95	−0.4	6	10,956	n.	48	n.	10	15	10	6	4.2	7.6	0.8
Southern Slope.							**34.4**	**−4.8**											**61**	**0.65**	**0.0**									**3.6**		
Abilene	1,738	10	52	28.15	30.01	−0.08	36.6	−6.0	75	25	50	1	11	23	47	29	21	59	0.91	0.0	6	8,629	n.	43	sw.	13	15	9	7	3.8	9.1	0.0
Amarillo	3,676	10	49	26.16	30.01	− .05	30.7	−3.2	74	3	44	−8	11	17	51	24	19	73	1.01	+0.4	7	8,398	nw.	40	n.	10	24	3	4	3.7	10.1	0.0
Del Rio	944	64	71	29.00	30.01	− .05	46.4	−3.8	85	26	61	12	11	32	56	.....	.....	.....	0.05	−0.8	2	5,231	e.	54	nw.	10	21	6	4	2.6	0.5	0.0
Roswell	3,566	75	85	26.28	29.98	− .06	32.8	−6.4	75	3	48	−8	22	18	52	26	14	52	0.73	+0.2	5	6,162	s.	48	nw.	15	15	8	8	4.3	7.4	0.0
Southern Plateau.							**40.1**	**−0.7**											**52**	**1.03**	**+0.1**									**2.9**		
El Paso	3,762	110	133	26.13	29.96	−0.05	41.5	−2.6	69	4	53	8	22	30	36	34	24	54	1.20	+0.7	6	8,701	w.	56	w.	9	21	6	4	3.2	5.5	0.0
Santa Fe	7,013	57	66	23.07	29.96	− .08	26.2	−2.3	59	2	36	−1	21	16	32	22	17	74	1.63	+1.0	11	6,004	n.	34	s.	9	12	14	5	4.7	22.7	2.5
Flagstaff	6,908	8	57	23.23	29.94	− .11	25.4	−1.3	62	3	40	−13	28	11	43	.....	.....	.....	1.33	−0.7	6	.....	w.	37	e.	6	17	10	4	.....	17.5	6.5
Phoenix	1,108	76	81	28.80	29.98	− .05	49.6	−0.4	80	1	64	27	23	36	42	40	28	50	1.14	0.0	4	3,850	e.	26	w.	9	19	7	5	3.0	0.0	0.0
Yuma	141	9	54	29.85	30.00	− .05	54.3	−0.4	82	1	68	31	28	40	41	43	28	42	0.81	+0.4	2	4,453	n.	39	n.	10	27	2	2	1.4	0.0	0.0
Independence	3,910	11	42	26.00	30.03	− .04	43.2	+2.7	71	4	56	20	21	30	39	32	17	38	0.06	−0.8	1	.....	nw.	.....	.....	.....	23	4	4	2.1	T.	0.0
Needles	488	4	.....	29.49	30.01	.....	50.8	.....	78	2	64	28	16	37	38	.....	.....	.....	0.26	.....	3	.....	.....	.....	.....	.....	16	8	7	.....	0.0	0.0
Middle Plateau.							**30.2**	**+1.5**											**66**	**1.10**	**0.0**									**4.9**		
Reno	4,532	74	81	25.54	30.17	+0.04	33.3	+3.8	60	1	49	12	27	24	36	30	20	55	0.13	−1.8	3	4,086	w...	40	w...	7	17	9	5	4.0	0.1	0.0
Tonopah	6,090	12	20	24.05	30.11	.....	31.6	.....	58	2	39	6	10	24	23	27	19	60	0.22	−0.5	3	7,212	w...	37	nw.	9	21	7	3	2.7	2.5	0.0
Winnemucca	4,344	18	56	25.68	30.17	+ .01	31.8	+3.0	61	2	44	−1	10	20	44	27	22	68	1.04	0.0	6	5,188	sw.	28	nw.	26	7	11	13	6.1	5.9	0.0
Modena	5,479	10	43	24.58	30.05	− .05	28.2	+0.7	65	3	43	0	21	14	43	23	14	59	0.11	−0.6	4	7,303	w.	39	nw.	18	16	6	9	4.0	1.8	0.0
Salt Lake City	4,330	163	203	25.61	30.08	− .07	30.4	+1.8	53	2	3	10	10	24	22	28	24	76	3.89	+2.5	17	4,091	se.	28	nw.	29	5	12	14	6.9	31.0	8.5
Grand Junction	4,602	82	96	25.35	30.03	− .03	23.2	−1.7	58	2	33	1	22	14	34	21	17	79	1.18	+0.7	14	3,667	se.	21	se.	11	10	11	10	5.5	15.9	4.5
Northern Plateau.							**33.1**	**+4.3**											**80**	**2.20**	**+0.6**									**7.7**		
Baker	3,471	48	53	26.48	30.15	−0.01	28.8	+4.9	54	1	33	−9	31	22	25	27	24	81	1.93	+0.6	17	3,937	se.	27	nw.	9	6	6	19	7.3	15.1	2.0
Boise	2,739	78	83	27.23	30.16	− .03	34.4	+5.1	53	1	41	9	31	28	22	32	28	78	2.27	+0.4	18	3,561	nw.	33	nw.	9	5	6	20	7.3	4.9	T.
Lewiston	757	40	48	29.29	30.12	− .04	33.4	+1.9	59	1	42	6	31	30	21	.....	.....	.....	3.12	+1.5	21	2,580	e.	30	sw.	28	3	6	22	8.2	15.1	0.4
Pocatello	4,477	60	68	25.44	30.08	− .12	27.6	+2.5	57	3	35	−7	31	20	29	23	23	80	1.94	+1.3	17	8,327	se.	40	sw.	29	3	9	19	7.5	21.7	8.0
Spokane	1,929	101	110	28.00	30.11	− .01	31.6	+4.9	62	1	37	3	31	27	24	30	27	83	1.66	−0.6	16	4,065	sw.	34	sw.	28	4	4	23	8.3	8.7	T.
Walla Walla	991	57	65	29.04	30.13	− .02	39.8	+6.6	67	1	46	10	31	33	22	37	33	78	2.29	+0.3	17	3,910	s.	27	sw.	18	4	8	19	7.4	3.7	T.
North Pacific Coast Region.							**44.8**	**+4.7**											**83**	**6.13**	**−0.8**									**8.1**		
North Head	211	11	56	29.88	30.12	+0.07	45.5	+3.7	55	6	49	23	31	42	30	45	44	93	7.47	+0.8	25	13,870	nw.	72	se.	17	3	2	26	8.5	0.0	0.0
North Yakima	1,071	4	.....	.....	.....	.....	35.0	.....	55	24	43	7	31	27	23	.....	.....	.....	0.64	.....	4	.....	nw.	.....	.....	.....	10	11	10	.....	3.0	0.0
Port Angeles	29	8	53	.....	30.08	.....	41.6	.....	56	1	46	20	31	37	17	.....	.....	.....	2.62	−2.8	21	4,647	w.	32	nw.	8	3	4	24	.....	.....	.....
Seattle	125	215	250	29.99	30.12	+ .07	43.7	+4.4	60	1	48	24	31	40	13	42	38	81	2.94	−1.6	19	7,711	se.	42	s.	28	1	5	25	8.6	0.0	0.0
Tacoma	213	113	120	29.89	30.12	+ .08	43.6	+5.5	63	1	48	22	31	39	16	42	39	84	4.14	−1.6	16	5,317	sw.	30	sw.	28	2	6	23	8.2	T.	0.0
Tatoosh Island	86	7	57	29.96	30.03	+ .08	44.5	+3.3	55	1	47	29	30	42	11	43	41	88	13.98	+1.8	27	14,446	e.	56	s.	1	4	3	24	8.4	T.	0.0
Medford	1,425	4	.....	.....	.....	.....	41.2	.....	58	5	49	22	31	33	25	.....	.....	.....	2.17	.....	16	.....	nw.	.....	.....	.....	3	20	8	.....	0.0	0.0
Portland, Oreg.	153	68	103	29.99	30.15	+ .07	45.4	+6.3	59	4	50	24	31	41	14	43	40	80	4.68	−1.8	22	4,737	sw.	29	e.	31	0	9	22	8.2	0.0	0.0
Roseburg	510	9	57	29.64	30.21	+ .11	45.8	+5.0	61	17	51	27	31	40	19	44	41	85	3.56	−2.1	18	1,809	s.	18	s.	14	1	20	10	6.5	0.0	0.0
Middle Pacific Coast Region.							**49.2**	**+1.9**											**70**	**1.13**	**−3.6**									**4.3**		
Eureka	62	73	89	30.14	30.21	+0.11	48.4	+1.5	63	3	54	33	31	43	19	47	45	87	2.55	−5.1	17	5,059	se.	44	n.	25	8	8	15	6.0	0.0	0.0
Mount Tamalpais	2,375	11	18	27.62	30.11	.00	47.6	+1.7	67	1	53	36	31	42	20	42	35	61	1.06	−4.9	5	17,104	n.	80	nw.	29	18	7	6	3.7	0.0	0.0
Point Reyes Light	490	7	18	29.57	30.09	.....	51.0	+1.6	65	1	55	42	31	47	20	.....	.....	.....	0.82	.....	4	14,134	nw.	70	nw.	25	15	10	6	4.1	0.0	0.0
Red Bluff	332	50	56	29.79	30.16	+ .04	47.8	+2.4	73	23	55	30	21	40	31	42	33	64	0.67	−3.3	3	4,164	n.	33	n.	25	16	4	11	4.6	0.0	0.0
Sacramento	69	106	117	30.07	30.15	+ .03	47.5	+1.9	67	27	56	32	30	39	30	42	35	66	0.97	−2.7	2	4,983	nw.	37	nw.	9	13	7	11	5.2	0.0	0.0
San Francisco	155	209	213	29.96	30.13	+ .02	52.7	+3.2	64	28	59	41	2	46	20	47	41	70	0.81	−3.5	3	4,385	n.	27	ne.	20	20	6	5	2.7	0.0	0.0
San Jose	141	12	110	29.97	30.20	.....	49.4	+1.2	70	24	60	28	31	38	34	.....	.....	.....	0.70	−2.2	4	3,950	nw.	31	nw.	26	16	9	6	4.1	0.0	0.0
South Pacific Coast Region.							**52.6**	**+1.7**											**67**	**0.79**	**−2.0**									**3.8**		
Fresno	327	89	98	29.77	30.14	+0.04	46.4	+1.0	68	24	56	30	10	37	32	41	35	67	0.47	−1.1	2	3,405	nw.	18	nw.	7	15	5	11	5.0	0.0	0.0
Los Angeles	338	159	191	29.57	30.04	− .04	55.7	+2.6	82	1	65	42	2	46	33	48	41	65	0.50	−2.3	4	4,165	ne.	32	nw.	9	17	8	6	3.8	0.0	0.0
San Diego	87	62	70	29.93	30.03	− .04	54.4	+0.4	69	24	62	39	21	47	25	49	43	71	1.64	−0.4	5	3,982	e.	38	s.	24	18	8	5	3.2	0.0	0.0
San Luis Obispo	201	32	40	29.88	30.10	+ .01	53.8	+2.7	84	1	66	31	28	42	45	47	41	65	0.55	−4.2	3	3,267	nw.	20	n.	3	18	9	7	3.3	0.0	0.0
West Indies.																																
San Juan, P. R	82	8	54	29.93	30.02	0.00	73.8	.....	84	3	80	64	7	68	17	.....	.....	.....	1.26	−3.4	16	9,223	e.	34	e.	27	11	18	2	4.4	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.74	29.86	.....	78.4	.....	90	26	86	66	6	71	20	72	71	88	1.78	+0.8	7	6,254	nw.	27	n.	13	7	22	2	4.5	0.0	0.0
Colon	36	30	97	29.84	29.88	.....	78.0	.....	84	26	81	70	2	75	9	74	73	84	3.28	−0.6	12	9,462	ne.	35	nw.	8	5	23	3	4.9	0.0	0.0
Alaska.																																
Juneau	80	11	49	.....	.....	.....	30.1	.....	46	3	34	10	30	26	17	28	25	80	8.63	.....	24	3,240	se.	27	ne.	16	2	2	27	8.8	36.3	11.6

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during January, 1918, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	21			0.51														0.10			
Albany, N. Y.	12			0.96														*			
Alpena, Mich.	11-12			0.46														*			
Amarillo, Tex.	10			0.48														*			
Anniston, Ala.	28	7:28 a. m.	2:15 p. m.	0.76	8:04 a. m.	8:26 a. m.	0.01	0.31	0.41	0.52	0.62	0.64									
Asheville, N. C.	30			0.64														0.23			
Atlanta, Ga.	28			1.89														0.57			
Atlantic City, N. J.	15			1.24														0.53			
Augusta, Ga.	28			0.89														0.25			
Baker, Oreg.	10-11			0.84														*			
Baltimore, Md.	11-12			1.83														*			
Bentonville, Ark.	10-11			0.85														*			
Binghamton, N. Y.	11-12			0.95														*			
Birmingham, Ala.	10-11	10:45 p. m.	8:52 a. m.	1.81	6:01 a. m.	6:37 a. m.	1.07	0.18	0.22	0.33	0.41	0.52	0.61	0.70	0.73						
	28	D. N. a. m.	1:20 p. m.	1.37	6:12 a. m.	6:59 a. m.	0.04	0.19	0.37	0.48	0.57	0.67	0.82	0.87	0.88	0.99	1.04				
Bismarck, N. Dak.	7-8			0.22														*			
Block Island, R. I.	15			0.86														0.28			
Boise, Idaho	11-12			0.62														*			
Boston, Mass.	15			0.86														0.27			
Buffalo, N. Y.	15			1.15														*			
Burlington, Vt.	15			0.84														*			
Cairo, Ill.	10-11			0.94														*			
Canton, N. Y.	7-8			0.53														*			
Charles City, Iowa	26			0.19														*			
Charleston, S. C.	31			0.17														0.15			
Charlotte, N. C.	14-15			0.89														0.40			
Chattanooga, Tenn.	28			0.95														0.36			
Cheyenne, Wyo.	18-19			0.16														*			
Chicago, Ill.	6			1.44														*			
Cincinnati, Ohio	6			0.90														0.29			
Cleveland, Ohio	14-15			0.70														*			
Columbia, Mo.	5-6			0.38														*			
Columbia, S. C.	14-15			0.48														0.35			
Columbus, Ohio	6			0.68														*			
Concord, N. H.	15			0.65														*			
Concordia, Kans.	9-10			0.71														*			
Corpus Christi, Tex.	11			0.05														0.02			
Dallas, Tex.	14			0.75														0.38			
Davenport, Iowa	6			0.70														*			
Dayton, Ohio	5-6			1.17														*			
Del Rio, Tex.	10			0.03														*			
Denver, Colo.	26			0.20														*			
Des Moines, Iowa	27			0.32														*			
Detroit, Mich.	6-7			0.73														*			
Devils Lake, N. Dak.	4			0.08														*			
Dodge City, Kans.	9-10			0.67														*			
Drexel, Nebr.	26-27			0.18														*			
Dubuque, Iowa	5-6			0.72														*			
Duluth, Minn.	1			0.48														*			
Eastport, Me.	3-4			1.00														*			
Elkins, W. Va.	26			0.74														0.22			
Ellendale, N. Dak.	23			0.12														*			
El Paso, Tex.	9-10			0.70														*			
Erie, Pa.	15			0.46														*			
Escanaba, Mich.	11-12			0.23														*			
Eureka, Cal.	12			1.16														0.32			
Evansville, Ind.	14-15			1.96														*			
Flagstaff, Ariz.	26			0.69														*			
Fort Smith, Ariz.	14			0.75														*			
Fort Wayne, Ind.	1-2			0.68														*			
Fort Worth, Tex.	14			0.69														0.50			
Fresno, Cal.	12			0.43														0.18			
Galveston, Tex.	14			0.21														0.20			
Grand Haven, Mich.	6-7			0.81														*			
Grand Junction, Colo.	5-6			0.26														*			
Grand Rapids, Mich.	6-7			1.02														*			
Green Bay, Wis.	6-7			0.68														*			
Greenville, S. C.	11			2.67														0.46			
Hannibal, Mo.	10-11			0.28														*			
Harrisburg, Pa.	14-15			1.60														*			
Hartford, Conn.	11-12			1.25														*			
Hatteras, N. C.	17-18			0.33														*			
Havre, Mont.	17-18			0.33														*			
Helena, Mont.	28-29			0.25														*			
Houghton, Mich.	12-13			0.43														*			
Houston, Tex.	29			0.33														*			
Huron, S. Dak.	8			0.19														*			
Independence, Cal.	25			0.06														*			
Indianapolis, Ind.	11			0.87														*			
Iola, Kans.	27			0.31														*			
Jacksonville, Fla.	15			0.45														0.44			
Kalispell, Mont.	19			0.25														*			
Kansas City, Mo.	10-11			0.34														*			
Keokuk, Iowa	27			0.27														*			
Key West, Fla.	7			0.56														0.41			
Knoxville, Tenn.	27			0.37														0.28			
La Crosse, Wis.	5-6			0.39														*			
Lander, Wyo.	18-19			0.47														*			
Lansing, Mich.	6-7			0.73														*			
Lewiston, Idaho	11			0.63														*			
Lexington, Ky.	14			1.20														0.24			
Lincoln, Nebr.	27-28			0.33														*			
Little Rock, Ark.	5			0.90														0.89			
Los Angeles, Cal.	26			0.32														0.08			
Louisville, Ky.	14			1.22														*			
Ludington, Mich.	6-7			0.97														*			
Lynchburg, Va.	15			0.38														0.15			
Macon, Ga.	11	11:50 a. m.	5:35 p. m.	1.67	3:30 p. m.	5:13 p. m.	0.11	0.10	0.18	0.45	0.57	0.62	0.69	0.70	0.71	0.73	0.78	1.04	1.22	1.47	1.56
Madison, Wis.	5-6			0.56														*			
Marquette, Mich.	18-19			1.28														*			

* Self-register not in use.

† Record partly estimated.

‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during January, 1918, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Memphis, Tenn.	5			0.68														0.43			
Meridian, Miss.	5–6	D. N. p. m.	5:30 a. m.	1.24	11:53 p. m.	12:07 a. m.	0.02	0.14	0.45	0.57	0.26	0.33	0.43	0.50	0.72	0.93	0.97	1.13			
	10–11	D. N. p. m.	5:20 a. m.	1.57	3:12 a. m.	4:09 a. m.	0.37	0.09	0.22	0.25											
Miami, Fla.	6			0.33														0.33			
Milwaukee, Wis.	6			1.82														*			
Minneapolis, Minn.	29–30			0.10														*			
Mobile, Ala.	11			0.86														0.46			
Modena, Utah.	25–26			0.09														*			
Montgomery, Ala.	6	D. N. a. m.	5:45 a. m.	1.02	3:08 a. m.	3:29 a. m.	0.17	0.23	0.45	0.50	0.57	0.62									
	10–11	D. N. p. m.	11:05 a. m.	2.67	7:52 a. m.	8.29 a. m.	0.41	0.32	0.38	0.55	0.65	0.70	0.76	0.82	0.90						
					9:35 a. m.	10:22 a. m.	1.48	0.16	0.35	0.49	0.61	0.64	0.66	0.72	0.85	1.06	1.10				
	11	11:55 a. m.	1:34 p. m.	0.89	12:53 p. m.	1:18 p. m.	0.17	0.16	0.34	0.45	0.55	0.68									
Moorhead, Minn.	23			0.19														*			
Mount Tamalpais, Cal.	12			0.57														0.17			
Nantucket, Mass.	7			0.54														0.32			
Nashville, Tenn.	27			2.88														0.41			
New Haven, Conn.	11–12			1.11														*			
New Orleans, La.	14	12:40 p. m.	3:15 p. m.	0.85	2:05 p. m.	2:46 p. m.	0.03	0.05	0.15	0.20	0.24	0.29	0.47	0.52	0.74	0.77					
New York, N. Y.	15			0.78														0.35			
Norfolk, Va.	29			0.33														0.17			
Northfield, Vt.	15			0.82														*			
North Head, Wash.	15			1.35														0.34			
North Platte, Nebr.	9–10			0.23														*			
Oklahoma, Okla.	10			0.61														*			
Omaha, Nebr.	27			0.24														*			
Oswego, N. Y.	11–12			0.60														*			
Palestine, Tex.	14			0.72														0.45			
Parkersburg, W. Va.	15			0.23														0.11			
Pensacola, Fla.	14	11:40 a. m.	7:12 p. m.	0.92	5:58 p. m.	6:11 p. m.	0.06	0.33	0.65	0.80											
Peoria, Ill.	6			0.97														*			
Philadelphia, Pa.	15			0.96														*			
Phoenix, Ariz.	25			0.71														0.23			
Pierre, S. Dak.	25–26			0.46														*			
Pittsburgh, Pa.	14–15			0.87														*			
Pocatello, Idaho.	30			0.36														*			
Point Reyes Light, Cal.	12			0.28														0.19			
Port Angeles, Wash.	17–18			0.61														*			
Port Huron, Mich.	11–12			0.66														*			
Portland, Me.	15			2.07														0.41			
Portland, Oreg.	17			0.47														0.24			
Providence, R. I.	12			1.01														*			
Pueblo, Colo.	13			0.28														*			
Raleigh, N. C.	21–22			1.12														*			
Rapid City, S. Dak.	25–26			0.64														*			
Reading, Pa.	11–12			1.65														*			
Red Bluff, Cal.	14			0.40														0.17			
Reno, Nev.	8			0.10														*			
Richmond, Va.	11–12			1.35														*			
Rochester, N. Y.	6–7			0.73														*			
Roseburg, Oreg.	8			0.42														0.26			
Roswell, N. Mex.	19–20			0.53														*			
Sacramento, Cal.	12			0.75														0.29			
Saginaw, Mich.	11–12			0.70														*			
St. Joseph, Mo.	27			0.45														*			
St. Louis, Mo.	5–6			0.50														*			
St. Paul, Minn.	29–30			0.11														*			
Salt Lake City, Utah.	12			1.13														*			
San Antonio, Tex.	10			0.10														*			
San Diego, Cal.	26			0.76														0.26			
Sand Key, Fla.	7			0.48														0.37			
Sandusky, Ohio.	14–15			0.50														*			
Sandy Hook, N. J.	15			1.29														0.62			
San Francisco, Cal.	14			0.45														0.26			
San Jose, Cal.	12			0.47														*			
San Luis Obispo, Cal.	12			0.44														0.20			
Santa Fe, N. Mex.	26–27			0.53														*			
Sault Ste. Marie, Mich.	11–12			0.17														*			
Savannah, Ga.	6			0.16														0.14			
Scranton, Pa.	14–15			1.72														*			
Seattle, Wash.	15			0.20														0.16			
Sheridan, Wyo.	18			0.67														*			
Shreveport, La.	14			0.63														0.58			
Sioux City, Iowa.	25–26			0.64														*			
Spokane, Wash.	6–7			0.56														*			
Springfield, Ill.	5–6			0.94														*			
Springfield, Mo.	10–11			0.69														*			
Syracuse, N. Y.	15			1.33														*			
Tacoma, Wash.	17			0.51														0.21			
Tampa, Fla.	6	10:50 a. m.	3:20 p. m.	1.53	11:32 a. m.	12:32 p. m.	0.07	0.15	0.21	0.31	0.34	0.39	0.45	0.49	0.52	0.55	0.63	1.00			
Tatoosh Island, Wash.	4			1.26														0.52			
Taylor, Tex.	10–11			0.36														*			
Terre Haute, Ind.	5–6			0.77														*			
Thomasville, Ga.	14	5:36 p. m.	D. N. p. m.	1.13	9:52 p. m.	10:16 p. m.	0.24	0.32	0.59	0.64	0.69	0.76									
Toledo, Ohio.	6			1.24														*			
Tonopah, Nev.	14			0.14														*			
Topeka, Kans.	10			0.28														*			
Trenton, N. J.	15			0.72														*			
Valentine, Nebr.	25–26			0.45														*			
Vicksburg, Miss.	5	6:35 p. m.	10:00 p. m.	1.00	7:48 p. m.	8:03 p. m.	0.04	0.36	0.64	0.74											
	27–28	9:12 p. m.	D. N. a. m.	1.51	10:56 p. m.	11:21 p. m.	0.20	0.12	0.24	0.52	0.73	0.85									
Walla Walla, Wash.	6–7			0.54														*			
Washington, D. C.	26			0.34														*			
Wausau, Wis.	1			0.44														*			
Wichita, Kans.	10			0.68														*			
Williston, N. Dak.	7			0.18														*			
Wilmington, N. C.	15			0.44														0.38			
Winnemucca, Nev.	12			0.33														0.17			
Wytheville, Va.	11			1.15														*			
Yankton, S. Dak.	25–26			0.57														*			
Yellowstone Park, Wyo.	25			0.24														*			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, January, 1918.*

Stations.	Altitude above M. S. L.* Jan. 1, 1916.	Pressure.			Temperature.						Precipitation.		
		Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.34	29.48	−0.38	29.4	+ 5.6	34.0	24.8	46	10	4.58	−1.33	15.0
Sydney, C. B. I.	48	29.62	29.66	−0.27	21.8	+ 1.3	30.6	13.0	43	−10	5.97	+0.87	26.5
Halifax, N. S.	88	29.58	29.69	− .28	20.9	− 0.9	29.0	12.8	41	− 8	3.59	−2.18	15.1
Yarmouth, N. S.	65	29.63	29.70	− .30	22.0	− 4.3	27.7	16.3	41	4	3.41	−2.00	22.9
Charlottetown, P. E. I.	38	29.62	29.66	− .30	16.5	− 0.5	23.0	10.1	42	− 9	2.78	−1.18	13.4
Chatham, N. B.	28	29.69	29.72	−0.25	11.1	+ 1.3	20.8	1.3	48	−26	3.78	+0.19	34.6
Father Point, Que.	20	29.57	29.60	− .38	8.2	+ 0.2	14.0	2.4	31	−14	2.49	−0.36	24.9
Quebec, Que.	296	29.47	29.81	− .21	6.1	− 3.0	13.2	− 1.0	34	−23	3.11	−0.90	31.1
Montreal, Que.	187	29.64	29.87	− .17	7.6	− 4.1	13.5	1.8	34	−19	3.40	−0.33	34.0
Stonecliffe, Ont.	489	29.23	29.88	− .14	2.7	− 3.7	11.5	− 6.1	22	−36	1.82	−0.50	18.2
Ottawa, Ont.	236	29.60	29.88	−0.15	5.8	− 3.8	14.9	− 3.3	29	−26	3.17	+0.18	31.7
Kingston, Ont.	285	29.57	29.91	− .14	8.7	− 8.4	17.7	− 0.3	35	−16	1.86	−1.59	18.4
Toronto, Ont.	379	29.47	29.91	− .14	13.2	− 8.2	20.4	6.0	33	− 8	2.30	−0.62	23.0
White River, Ont.	1,244	28.46	29.86	− .15	− 5.8	− 5.4	6.8	−18.4	19	−52	1.61	−0.08	16.1
Port Stanley, Ont.	592	29.26	29.94	− .13	12.5	− 9.7	20.0	5.0	35	− 8	2.49	−0.50	22.5
Southampton, Ont.	656	29.10	.....	.....	9.2	−11.2	16.9	1.5	32	−13	4.29	+0.24	42.9
Parry Sound, Ont.	688	29.14	29.88	−0.13	5.0	− 8.8	14.3	− 4.2	25	−20	6.90	+2.82	69.0
Port Arthur, Ont.	644	29.19	29.95	− .12	2.0	− 1.1	10.7	− 6.6	28	−30	0.34	−0.48	3.4
Winnipeg, Man.	760	29.19	30.10	− .01	− 5.2	+ 1.6	2.0	−12.5	22	−37	0.81	−0.07	8.1
Minnedosa, Man.	1,690	28.13	30.07	− .03	− 5.0	+ 2.2	4.6	−14.5	32	−43	0.42	−0.38	4.2
Qu'Appelle, Sask.	2,115	27.68	30.09	+0.01	− 4.0	− 0.2	4.9	−13.0	41	−36	1.09	+0.59	10.9
Medicine Hat, Alberta.	2,144	27.67	30.06	− .01	9.8	+ 4.3	19.3	0.4	48	−42	1.81	+1.24	18.1
Swift Current, Sask.	2,392	27.36	30.10	+ .01	4.1	+ 1.0	13.4	− 5.3	50	−36	0.96	+0.32	9.6
Calgary, Alberta.	3,428	26.36	30.08	+ .05	13.0	+ 4.6	24.5	1.6	54	−24	0.30	−0.23	3.0
Banff, Alberta.	4,521	25.28	30.07	+ .07	14.6	+ 2.5	23.4	5.9	48	−40	0.88	−0.31	7.9
Edmonton, Alberta.	2,150	27.65	30.07	+0.04	5.3	+ 3.5	15.1	− 4.5	44	−43	1.44	+0.76	14.4
Prince Albert, Sask.	1,450	28.49	30.17	+ .08	− 6.0	+ 2.4	3.5	−15.5	40	−46	0.91	−0.06	9.1
Battleford, Sask.	1,592	28.28	30.15	+ .07	− 4.7	+ 1.2	4.7	−14.1	43	−46	1.51	+1.11	14.9
Kamloops, B. C.	1,262	28.82	30.16	+ .20	25.2	+ 2.2	29.5	20.9	43	−14	1.87	+1.05	16.5
Victoria, B. C.	230	29.82	30.08	+ .11	42.0	+ 3.5	45.8	38.3	56	23	4.05	−1.34	T.
Barkerville, B. C.	4,180	25.60	30.02	+0.13	19.2	+ 1.4	25.5	13.0	40	22	7.65	+5.05	64.0
Hamilton, Bermuda.	151	29.82	29.99	− .14	61.4	− 0.6	66.5	56.3	72	51	3.80	−1.14	0.0

* See description of Table III given on p. 48.

Chart I. Hydrographs of Several Principal Rivers, January, 1918.

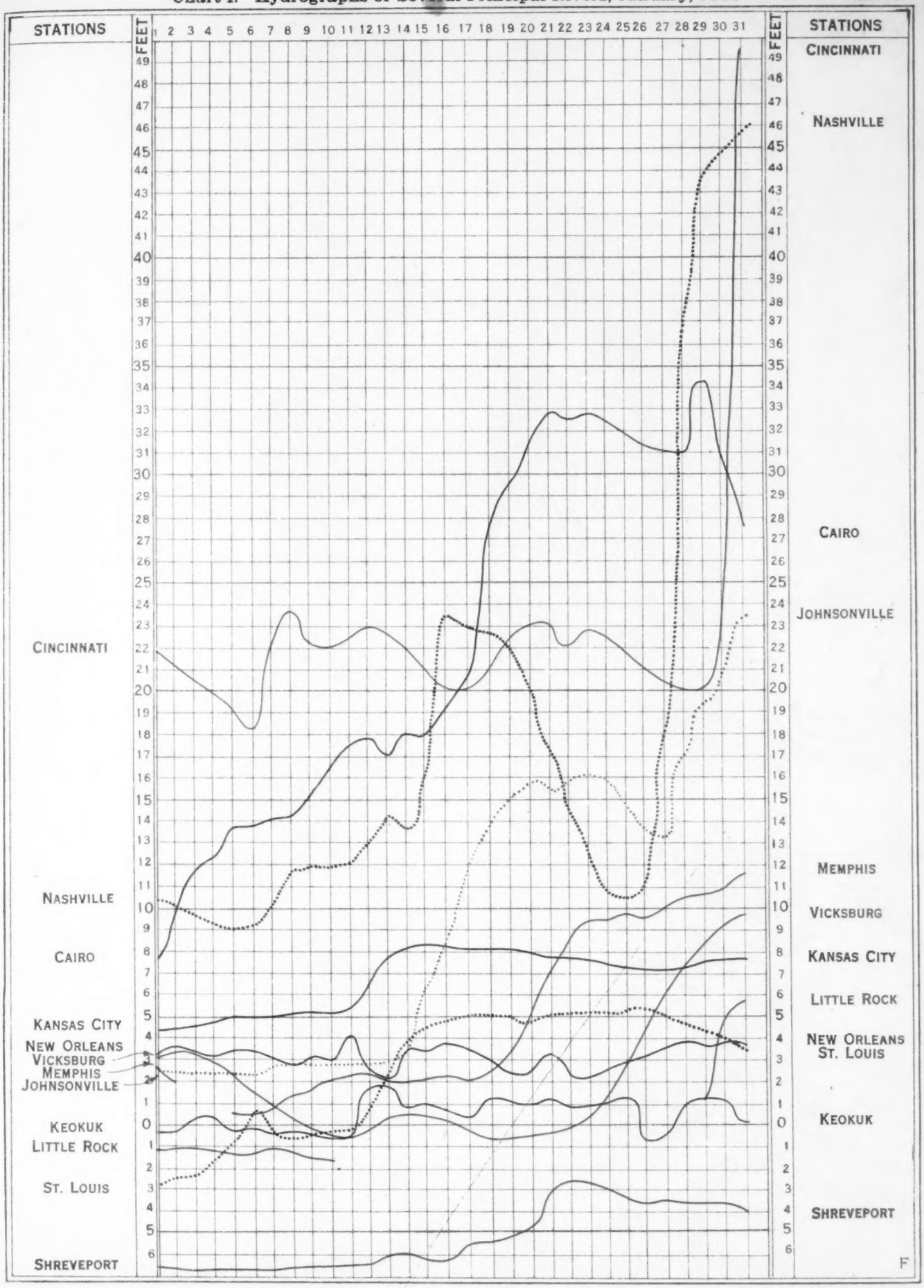


Chart II. Tracks of Centers of High Areas, January, 1918.

(Plotted by Charles A. Donnel.)

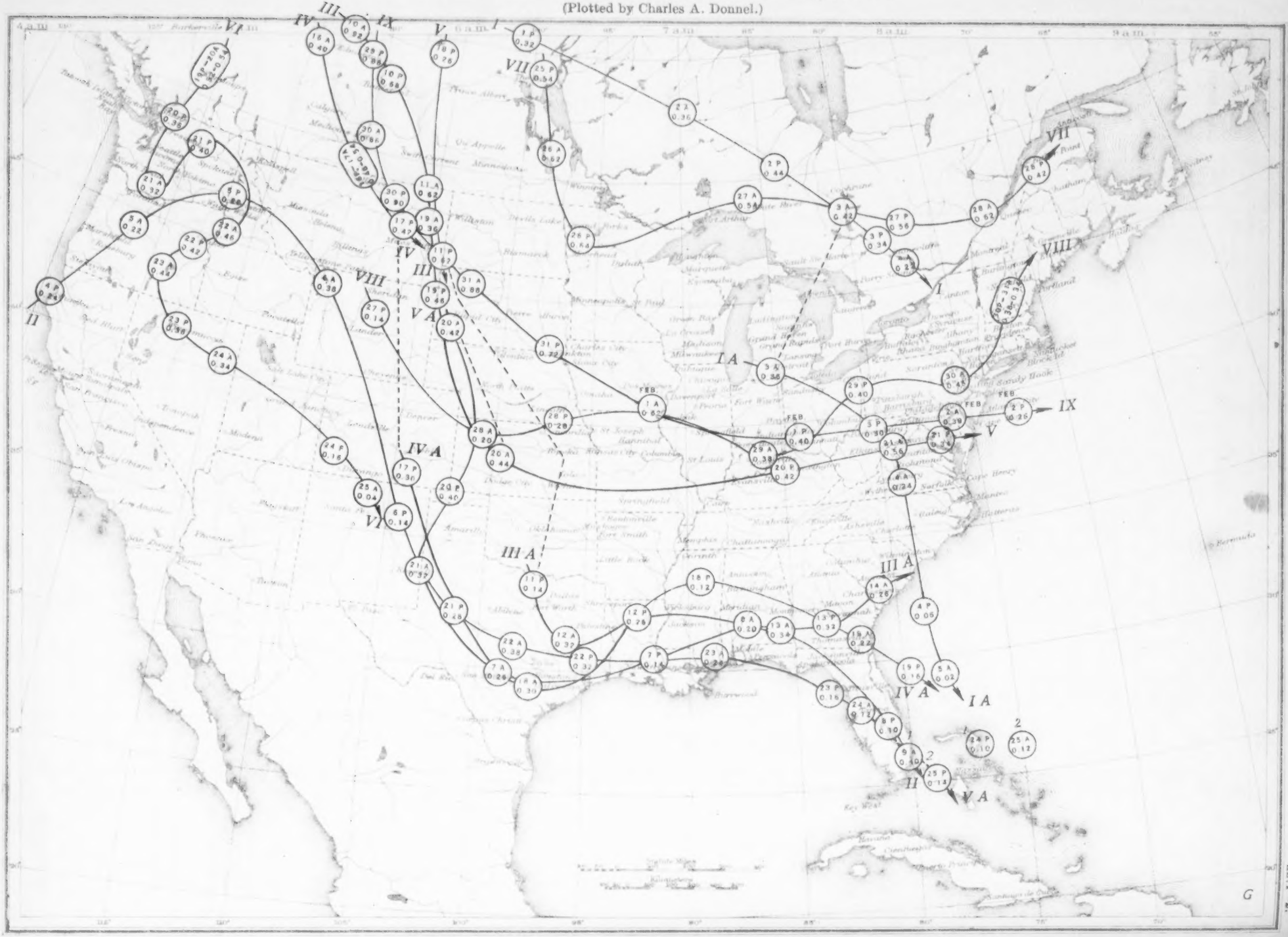


Chart III. Tracks of Centers of Low Areas, January, 1918.

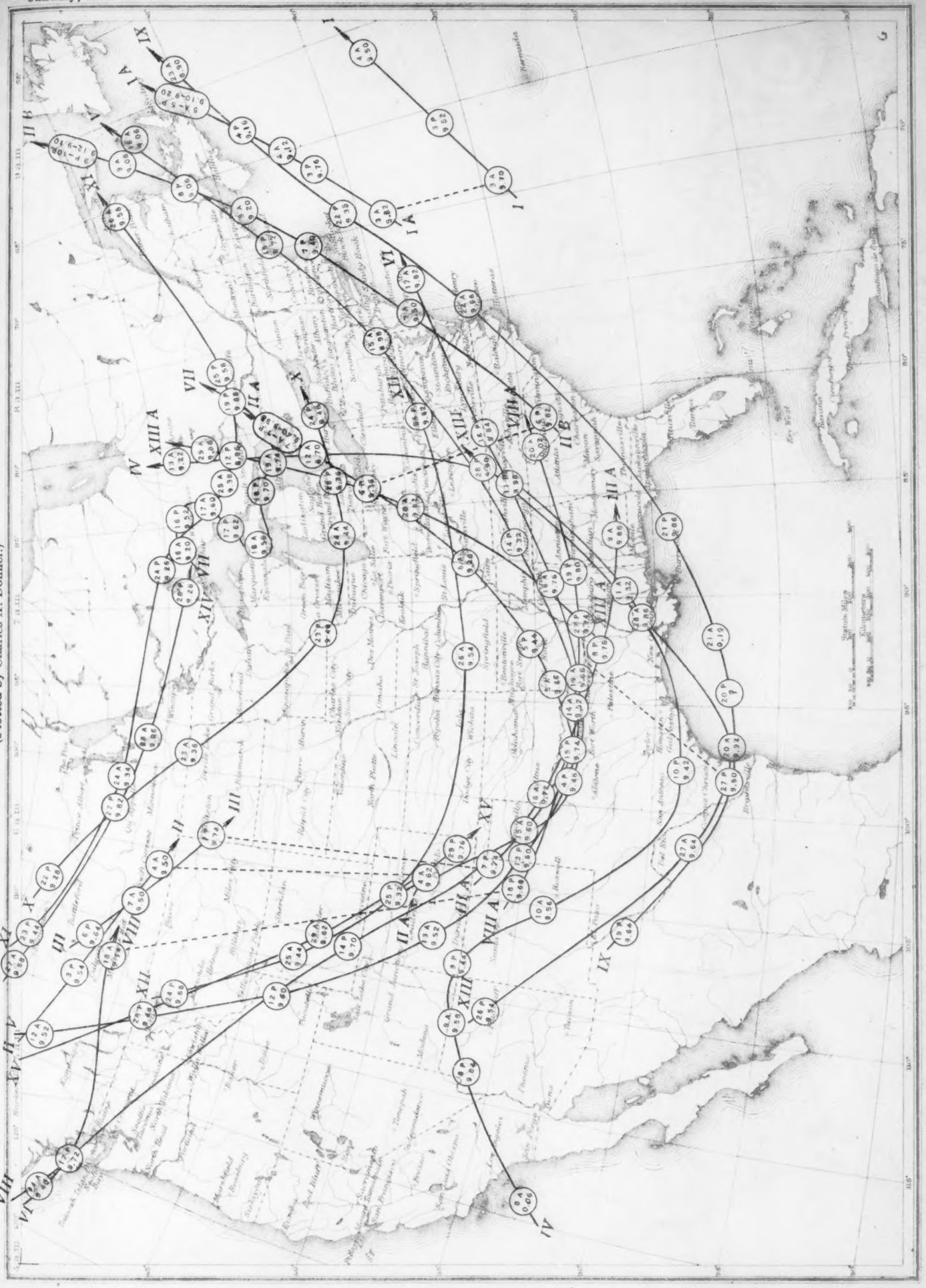


Chart III. Tracks of Centers of Low Areas, January, 1918.
(Plotted by Charles A. Donnel.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, January, 1918.

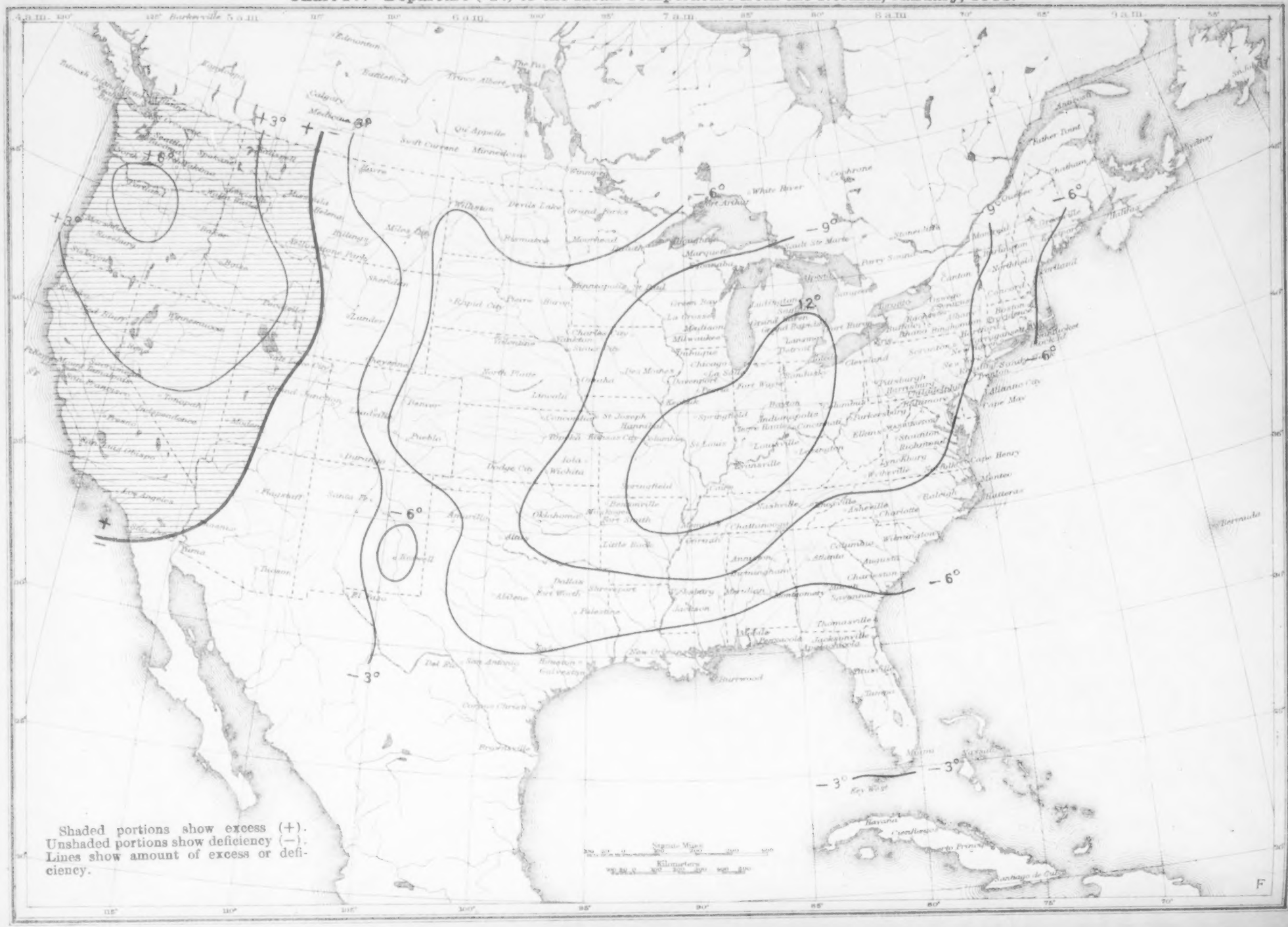


Chart V. Total Precipitation, January, 1918.

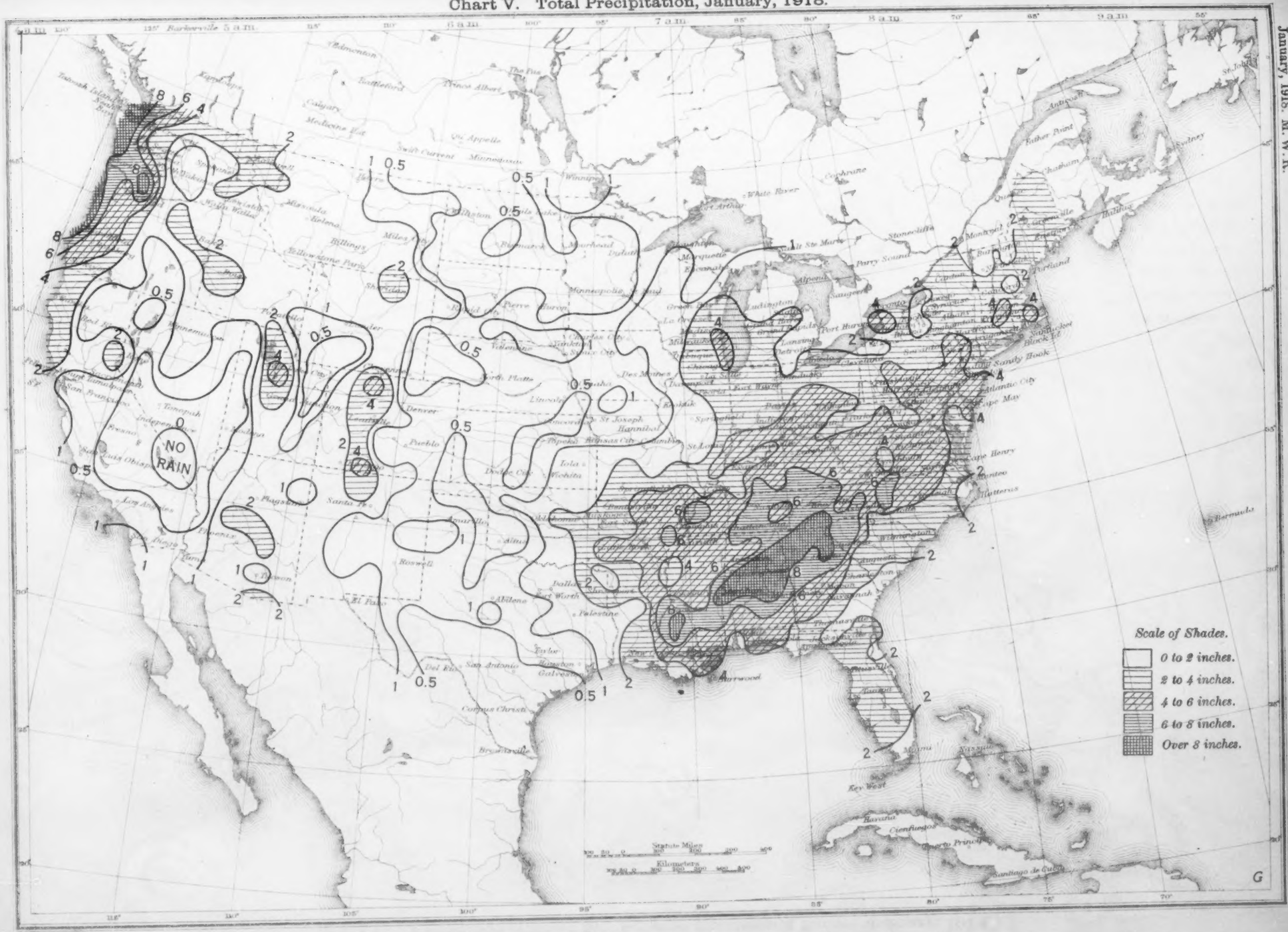


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, January, 1918.

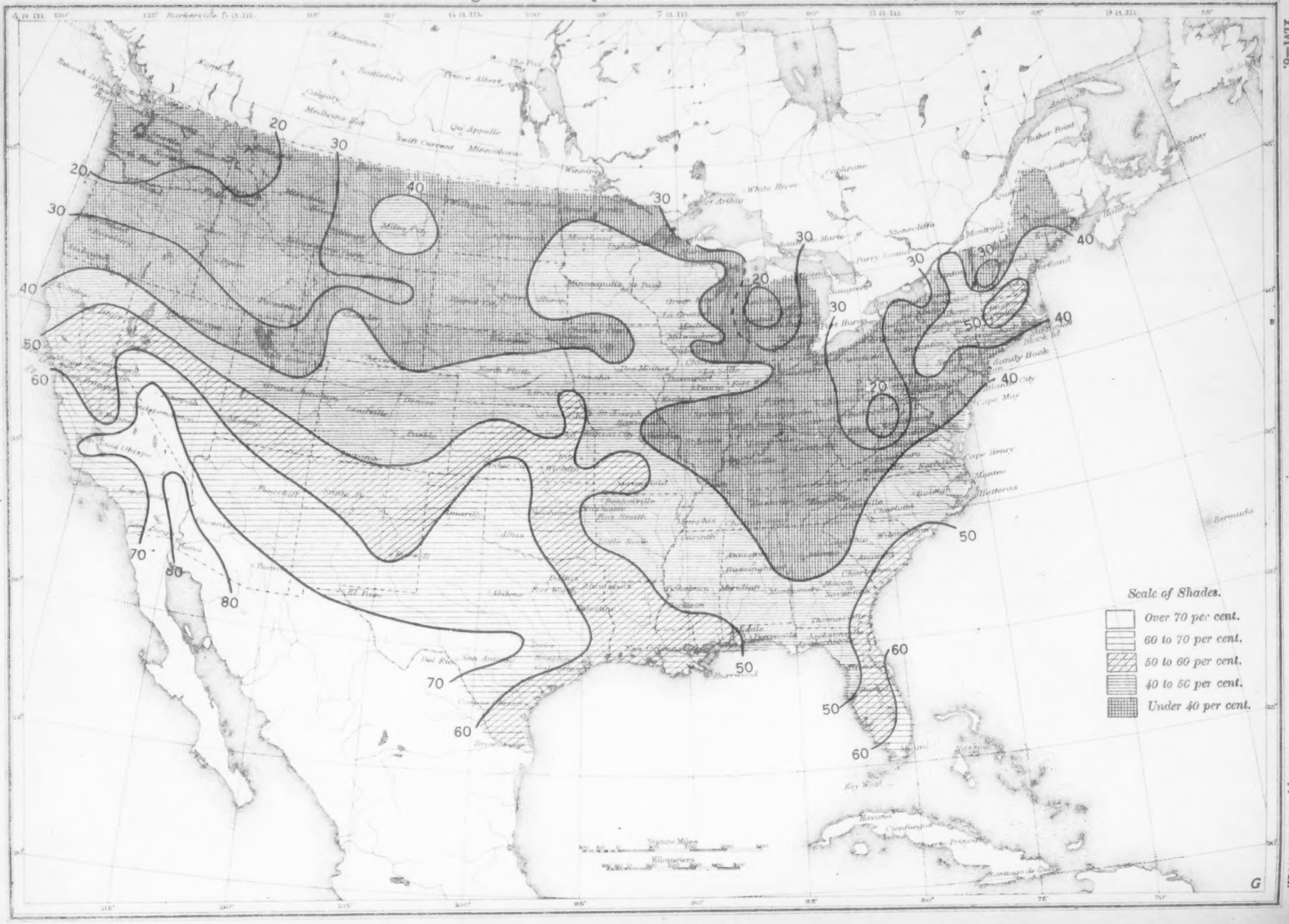


Chart VII. Isobars and Isotherms at Sea-level; Prevailing Winds, January, 1918.

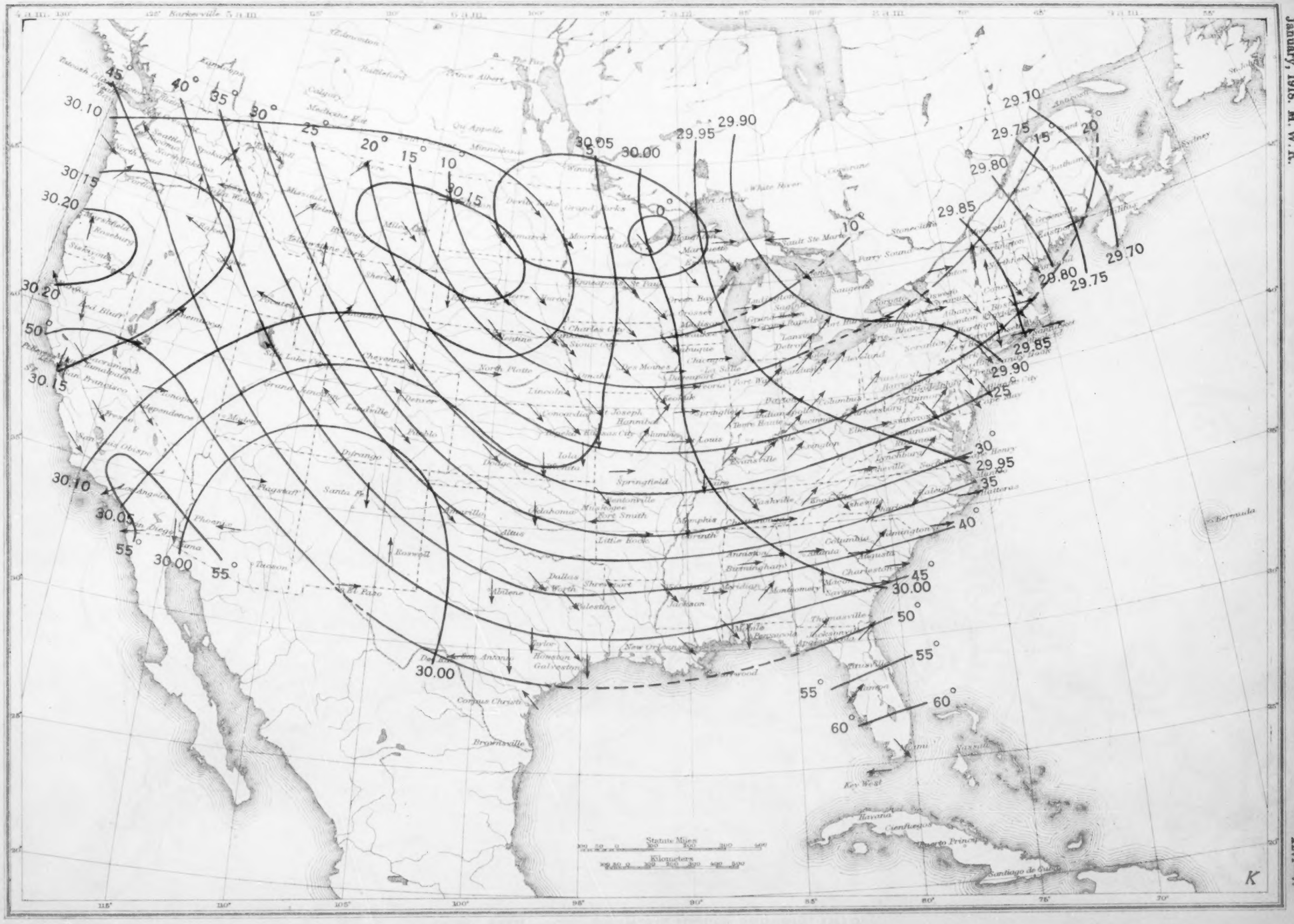


Chart VIII. Total Snowfall, Inches, January, 1918.

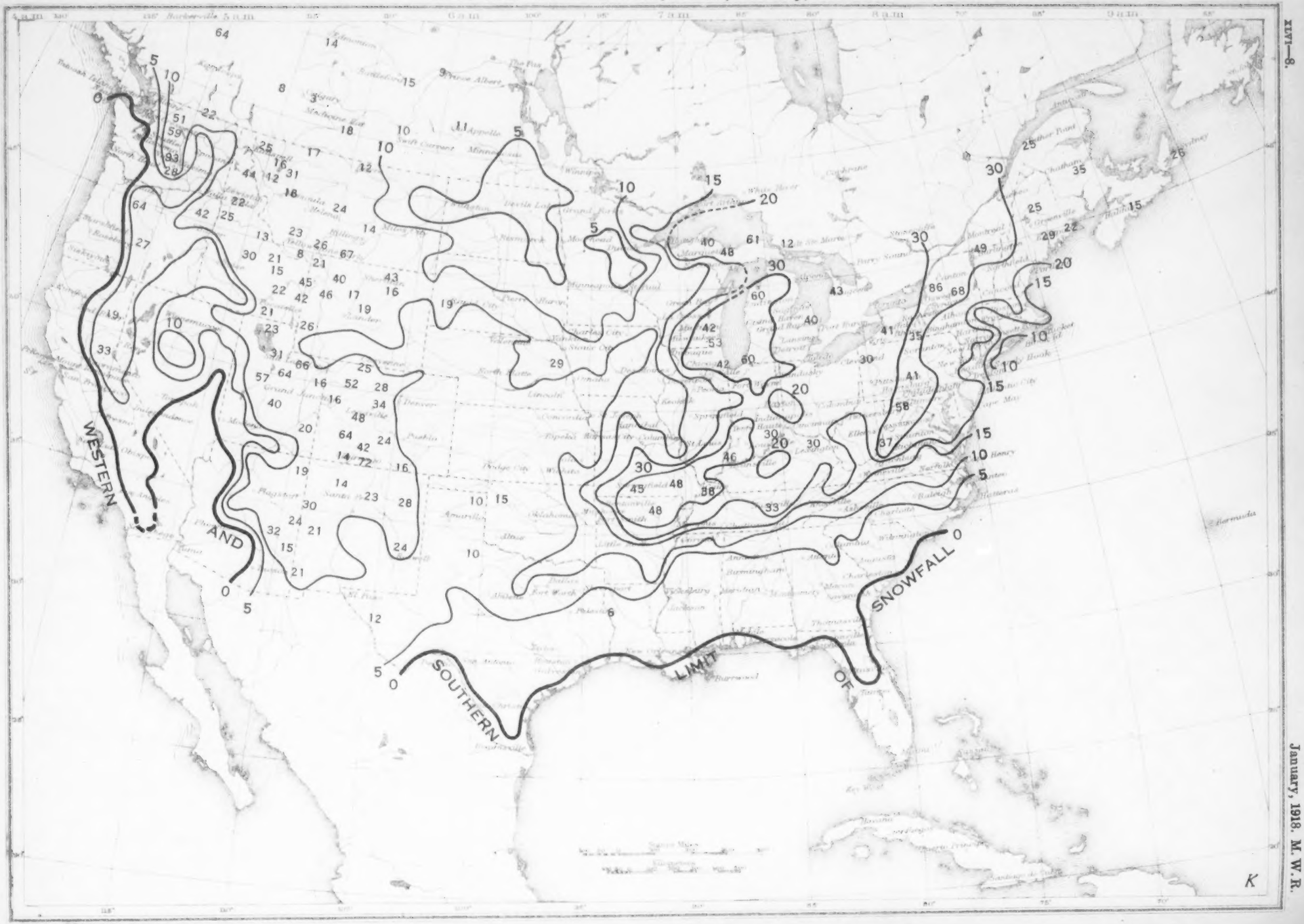
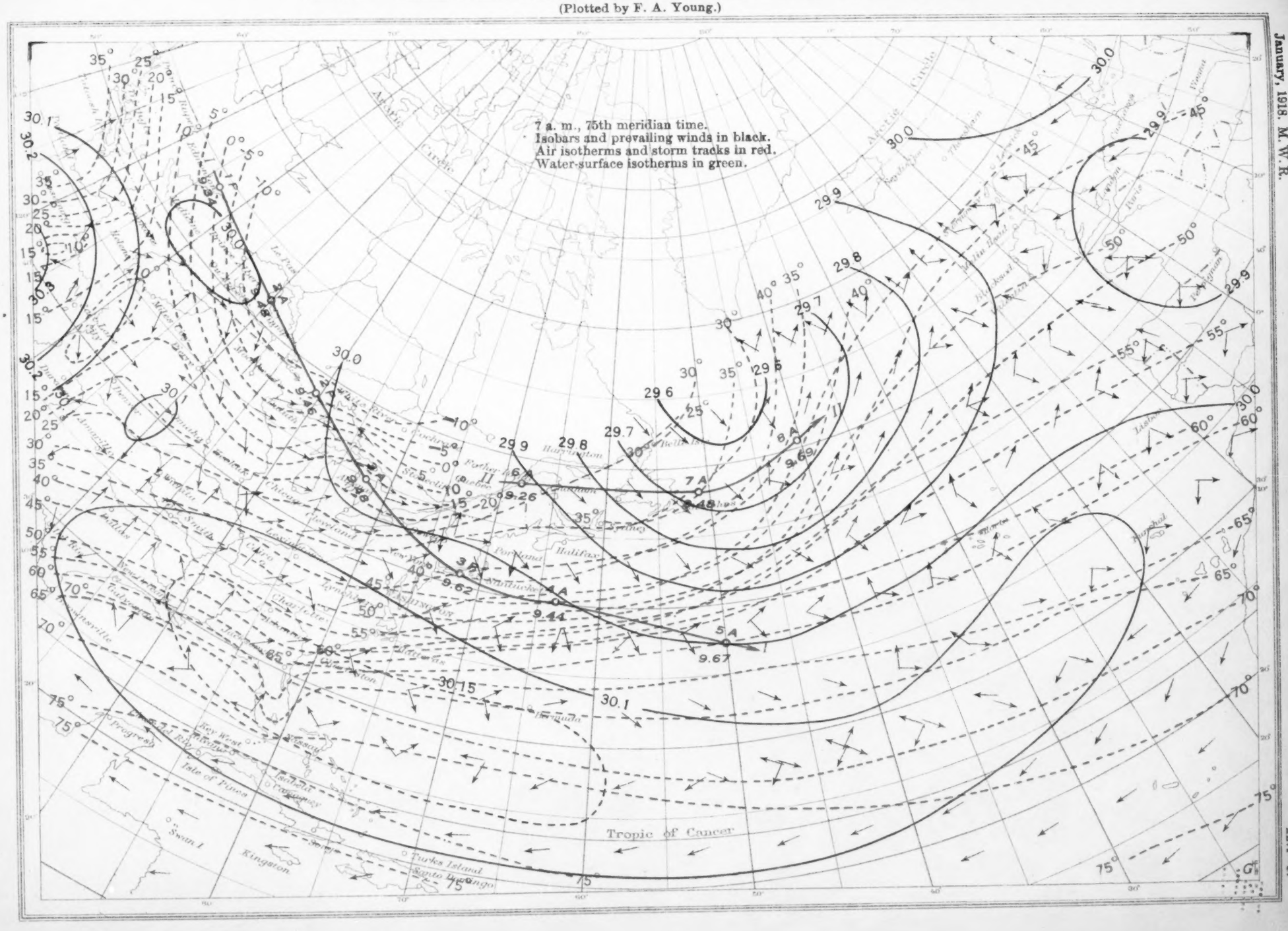


Chart IX. Means of Meteorological Data for North Atlantic Ocean, January, 1917.

(Plotted by F. A. Young.)


7 a. m., 75th meridian time.
Isobars and prevailing winds in black.
Air isotherms and storm tracks in red.
Water-surface isotherms in green.
Tropic of Cancer